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The impact of specialty, emotional involvement, and experience on the treatment indication of common lumbar spinal pathologies with clear level of evidence - The Indications in Spinal Surgery (INDIANA) survey

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Für meine Familie

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1. INTRODUCTION

1.1 Importance of the topic and current situation

In our society, low back pain (LBP) due to degenerative changes occurs with a lifetime prevalence of 84% and it is one of the most frequent reasons to consult a doctor (Freburger, et al., 2009). LBP is associated with social and economic problems and costs, as it causes a large proportion of days of incapacity to work, for example about 9% in Germany (Robert Koch-Institut in Zusammenarbeit mit dem Statistischen Bundesamt, 2012).

Due to this socioeconomic importance, it is even more important that the causes of back pain are diagnosed precisely and that the treatment is indicated properly and in accordance to the current state of science. Common causes of such episodes of LBP are degenerative changes in the lumbar spine such as lumbar disc herniation (DH), lumbar spinal stenosis (SS) and lumbar spondylolisthesis (SL) (Burton, et al., 2006; Hestbaek, Leboeuf-Yde, & Manniche, 2003).

Unfortunately, the scientific evidence in spinal surgery and for the treatment of degenerative spinal pathologies has been rather poor in recent decades. Although there were many different conservative and surgical treatment possibilities, there were no suitable studies that compared the patient outcome depending on therapy.

Since 2007, a number of randomized controlled trials (RCTs) have been conducted to compare patient outcome after conservative and surgical therapy. Especially two major RCTs, the Sciatica trial and the SPORT trial, now provide clear evidence for common degenerative spinal pathologies (Peul, et al., 2007; Weinstein J. , et al., SPORT: Spine patient outcomes research trial, 2006-2007).

But despite the existing level I evidence for the three most common degenerative lumbar spinal pathologies, such as lumbar DH, SS, and SL, the treatment indication still varies considerably. Therefore, it is important to identify factors that influence the treatment indication despite existing level I evidence for common spinal pathologies.

1.2 Possible factors for the variation in treatment indications

1.2.1 Medical specialty

Spine surgery is a medical field in which not only physicians from one, but from several medical specialties are active. Thus, spinal surgery is an intersection of neurosurgery and orthopedic/trauma surgery.

During their residency both disciplines undergo different training and use different surgical and conservative techniques. Depending on the medical specialty, the treatment and diagnosis of spinal pathologies takes up a varying proportion or extent of the overall residency training program (Daniels, et al., 2014; Bundesärztekammer, 2011).
The different medical specialty affiliations could therefore have an influence on the treatment indication in spinal surgery and could possibly be an explanation for the wide variability of the indication.
Unfortunately, most studies comparing neurosurgeons and orthopedic spine surgeons focus only on the patient outcome and not on the indication (Mabud, et al., 2016; Kim, Edelstein, Hsu, Lim, & Kim, 2014; Seicean, et al., 2014). They investigate complications, readmissions, and revisions for spinal surgeries performed by neurosurgeons and orthopedic spine surgeons and most of them find a similar and comparable outcome regarding most parameters. Only a marginal difference in patients' outcome for laminectomy with fusion was found between the medical specialties, but it seems to be small and not to be clinically meaningful (Mabud, et al., 2016). Kim et al. (2014) show no significant differences in the patients' 30-day complication rates between both specialties. Another work focuses on patient outcome after undergoing laminectomy and spinal fusion between neurosurgeons and orthopedic spine surgeons. They found some small differences, such as a significant longer hospitalization for patients operated on by orthopedic spine surgeons. Other 30-day complication rates did not differ significantly between both medical specialties (Seicean, et al., 2014).
Although these studies show us that both disciplines achieve a good and comparable outcome when treating spinal diseases, they do not investigate their treatment indication.
Only a few studies focus on differences in the treatment indication between neurosurgeons and orthopedic spine surgeons. However, some of them focus only on cervical spinal problems or traumatic injuries (Minhas, Chow, Patel, & Kim, 2014; Arnold, et al., 2009; Grauer, et al., 2004).
Thus, there are very few studies that investigate the indication for lumbar spinal pathologies between neurosurgeons and orthopedic spine surgeons at all (Lubelski, et al., 2016; Mroz, et al., 2014; Hussain, Nasir, Moed, & Murtaza, 2011). These studies focus only on the US and not on Europe or Germany. Summing up, due to the lack of scientific literature, the topic about differences in treatment indications for lumbar spinal pathologies between medical specialties needs to be further investigated.

1.2.2 Personal emotional involvement

In addition to the medical specialty, the personal emotional involvement of the physician to the treating patient could also lead to a variation in the treatment indication for degenerative spinal pathologies.

Physicians are confronted very often with the desire or request to provide medical care to their relatives, close family members, or friends. Sometimes just a professional opinion or medical advice is needed. But at times relatives require direct interference with their medication or even surgical interventions. At this point conflict of interests between the relative, the responsible physician, and the relative who happens to be a doctor are inevitable (Kerrigan, Rovelstad, Kodner, La Puma, & Keune, 2011; Reagan, Reagan, & Sinclair, 1994; La Puma, Stocking, La Voie, & Darling, 1991).

Numerous scientific articles published in the last 25 years show arguments for or against treating own family members as a physician (Chen, Feudtner, Rhodes, & Green, 2001; Evens, Lipton, & Ritz, 2007). Problems that might occur when doctors provide medical care to own relatives include dealing with own anxiety or other issues as confidentiality, privacy, and, most of all, objectivity (Schneck, 1998; Eastwood, 2009). On the other hand responsibility, economics, and convenience often convince physicians to prescribe medications or perform physical examination on own family members (Dusdieker, Murph, Murph, & Dungy, 1993; La Puma & Priest, 1992).

This phenomenon has existed for centuries. Already in 1803, Thomas Percival published his book “Medical Ethics” regarding the practice of physicians’ caring medically for their families (Percival, 1803). His book built the basis for the first ethical code of the American Medical Association (AMA) in 1847.

Until today many American organizations maintain Percival’s opinion about treating relatives and friends. In their guidelines they recommend treating family members and friends for minor conditions, in case of emergency, and when no other qualified professional is available (American Medical Association, 2016; American College of Physicians, 2012; College of Physicians and Surgeons of Ontario, 2007; General Medical Counsil, 2013).

Regarding surgeries for relatives or friends, these are clearly not minor conditions. The consequences of a poor outcome might have a higher emotional weight when treating family members. It is recommended that physicians critically evaluate the circumstances, risks, and consequences and to include experienced colleagues when deciding whether to operate on the relative or friend (Oberheu, Jones, & Sade, 2007). Another study recommends that physicians step aside and let another experienced colleague perform the intervention because of one’s own lack of objectivity (Jones, McCullough, & Richman, 2005).

Despite the clear guidelines in the US, which advise against treating one's own relatives and friends for major conditions, many studies from recent years show that the reality looks different. Especially in surgery it is common to operate and to treat own family members and friends (Moreno & Lucente, 1998; Slavin & Goldwyn, 2010).

In contrast to the US, there are no clear guidelines in Germany regarding the treatment of family members and friends. Unfortunately, also literature about whether to operate on family members and friends or not is still scarce, especially in Europe (Knuth, Bulian, Ansorg, & Büchlera, 2017).

In summary, emotional involvement in surgical procedures is a common problem that has been little researched so far and for which there is no clear regulation in Germany. This makes it all the more important to investigate the influence of emotional involvement on the treatment indication. Although lumbar spinal diseases are one of the most common causes to consult a physician, so far there exist no studies which investigate such influence on treatment indication. Therefore it is important to perform further research on this subject.

1.2.3 Experience

Another interesting aspect is to investigate whether and to what extent the individual clinical experience of the physician influences its treatment indication. It is possible that younger physicians with less working and clinical experience may refer more often to the scientific literature, acquired during medical school. Or, on the other hand, that older doctors with more experience in their discipline more often refer to scientific evidence since they have already experienced how and in which direction medicine is developing over the years.

In times of evidence-based medicine (EBM) the best scientific evidence from literature, together with clinical observation and experience builds the basis of decision-making. Non-systematic experience and obsolete knowledge thus lose ground and new, proven findings from scientific literature gain influence in medical decision-making (Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996).

Whether scientific evidence and individual experience have the same significance for the indication in spinal surgery, has so far, only been examined to a limited extent (Lubelski, et al., 2018). Especially since clear scientific evidence for the most common degenerative lumbar pathologies has only been available for a few years, it is possible that physicians' own clinical experience is even more important in decision-making than usually.

In this regard, it has not been investigated what kind of experience may lead to different indications. For example, the number of years of board certification or the number of surgeries performed by the physician himself could play a role that should not be underestimated.

1.3 Common spinal pathologies and their clinical approach

To investigate the variation in indications for spinal pathologies, it makes sense to resort to common pathologies with clear evidence.

Therefore, we examine our possible factors for variation in treatment indication (medical specialty, personal emotional relationship, experience) for the three most common degenerative spinal pathologies with clear level of evidence, on the basis of patient cases.

The three most common pathologies causing specific LBP and with existing level I evidence are lumbar DH, lumbar SS and lumbar SL (Deyo & Weinstein, 2001). Besides local back pain these different degenerative pathologies often irritate the nerve root and provoke lumbar radiculopathy, a leading symptom.

The clinical approach for the right treatment indication includes the knowledge of the clinical pathology, a good anamnesis, and clinical examination and the correct diagnostic approach.

1.3.1 Lumbar disc herniation

The lumbar intervertebral disc consists of a gelatinous core (nucleus pulposus) and a fibrous cartilaginous ring (annulus fibrosus). Due to the regression of the vascular supply and the decrease in the fluid content from the age of 20, the intervertebral disc becomes increasingly prone to injury. From the age of 50 the expansion pressure of the intervertebral disc decreases again. The peak frequency for disc herniations is therefore between the age of 30-50. Due to the aforementioned degenerative processes and microtraumas, the supporting ring, annulus fibrosus, of the intervertebral disc becomes crackly and the inner core, nucleus pulposus, bulges into the spinal canal. This is called a protrusion of the disc. When the bulging material is not covered from anulus anymore it is considered as a prolapse or herniation. *Figure 1* shows anatomical conditions for a normal disc and a herniated disc.

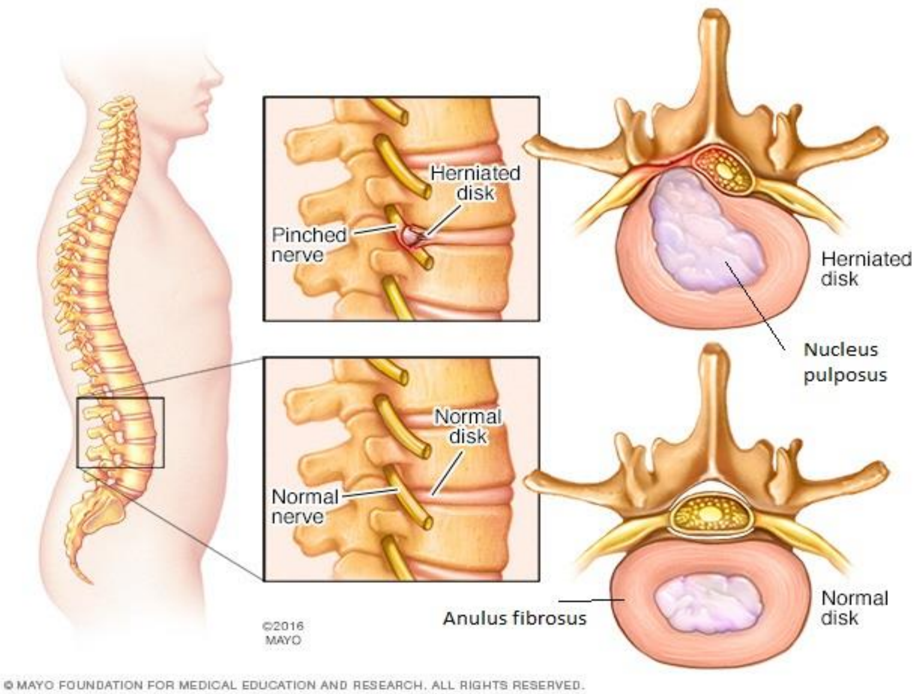

Figure 1: Graphical representation of a normal disc and a herniated disc

This picture illustrates the lumbar spine with a disc herniation (DH) compared to a healthy spine. It visualizes how the nucleus pulposus bulges and compresses the irritated nerve root. (1998-2018, Mayo Fondation for Medical Education and Research MFMER, https://www.mayoclinic.org/herniated-disk/img-20007695, 25.09.17)

Risk factors for lumbar DHs are overweight, lack of exercise, increased biomechanical stress and hyperlordosis of the lumbar spine. The pressure of the herniated disc on the spinal cord causes typical symptoms such as pain, sensory disturbances, paresis, weakening of muscle reflexes and myelopathies. Lumbar DH is the main cause for radiculopathy, a nerve root irritation, which can manifest as pain, paresthesia or paralysis along the nerve root and thus also up to the leg and to the toes. Pain symptoms depend on the localization of the prolapse. The local LBP, called lumbago, is caused by medial prolapse applying pressure to the posterior longitudinal ligament. If the nerve root is irritated and under compression, due to medio-lateral prolapses, also leg pain (sciatica) results. During clinical examination test to provoke sciatic nerve irritation such as supine straight-leg raise test (Laségue), often causes sciatica in patients with lumbar DH (Rabin, et al., 2007).

1.3.2 Lumbar spinal stenosis

Lumbar SS is by definition a reduction of the sagittal and cross diameter, thus a narrowing of the spinal canal. Verbiest defined absolute stenosis as a diameter left with lower than 10 mm and relative stenosis with a diameter between 10-14 mm (Verbiest, 1976). At the time, his definition was commonly accepted but nowadays it is criticized for using only intraoperative measurements, ignoring the individual shape of lumbar spine and not including intrusion of disc material or ligamentum flavum in the calculations (Cheung, Ng, Cheung, Samartzis, & Cheung, 2017). Since modern studies use different eligibility criteria for SS, it is difficult to compare them and to generalize results (Genevay, Atlas, & Katz, 2010).

SS is very common as degenerative stenosis in elderly people due to degenerative DH and thus to an overcharge of the facet joints and ligamentum flava (Beamer, Garner, & Shelden, 1973; Sairyo, et al., 2005). The overcharge hypertrophy of these structures causes a narrowing of the spinal canal and thus again compression of the nerves, as shown in *Figure 2.* Ligaments often are lax and thus instability or degenerative SL can result.

Main symptoms of SS are lumbago, means local LBP, and claudication or claudicatio spinalis (Thomé, 2009). This describes an intermittent limping due to pain and lameness of the legs which leads to a reduction of the walking distance.

Regarding treatment options, pain levels on the visual analogue scale (VAS) and free of pain walking distance, are helpful parameters during the decision-making process. If pain level goes from 0 to 4 and the walking distance without pain is about 500m, surgery should not be considered primarily. Pain levels from 6 to 10 and walking distance without pain of just a few meters, are absolute indications for surgery (Haak, Ludwig, Theodoridis, & Wild, 2005).

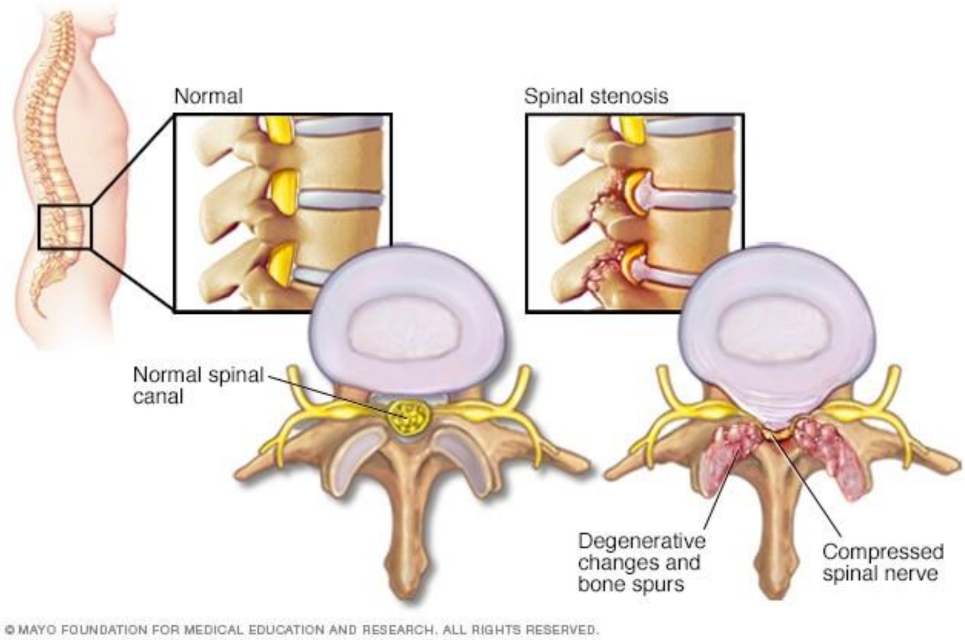

Figure 2: Normal spine and spinal stenosis

This illustration shows a healthy and normal lumbar spine without any narrowing of the spinal canal. On the right side the situation with spinal stenosis due to degenerative changes is illustrated. (1998-2018 Mayo Foundation for Medical Education and Research (MFMER) https://www.mayoclinic.org/diseases-conditions/spinal-stenosis/symptoms-causes/syc-20352961?_ga=2.23773049.233726002.1530529304-791516893.1530529304, 18.05.18)

1.3.3 Lumbar spondylolisthesis

„Olisthesis“ derives from Greek and means sliding or gliding. Hence SL means gliding of two vertebra, where the upper vertebra slides forward onto the lower vertebra. A graphical illustration of SL is given in *Figure 3*. It can be distinguished into different types, regarding its origin: dysplastic (congenital), isthmic (defect/absence of ossification of the pars interarticularis), degenerative, traumatic, and postoperative spondylolisthesis (Wiltse, Newman, & Macnab, 1976).

Often a “true” SL is distinguished from a “pseudospondylolisthesis”. SL due to spondylolysis, a defect of the pars interarticularis, is seen as “true” SL and is comparable to Wiltse et al. classification of an isthmic SL (Wiltse, Newman, & Macnab, 1976; Marchetti & Bartolozzi, 1997). In 1930, Junghanns was the first who wrote about “pseudospondylolisthesis” and used this term to describe the gliding of a vertebra with an intact neural arch (Junghanns, 1930). As degenerative SL occurs also with an intact neural arch or pars interarticularis, we nowadays use the term pseudospondylolisthesis almost equally to degenerative SL (Jacobsen, Sonne-Holm, Rovsing, Monrad, & Gebuhr, 2007; Newman & Stone, 1963).

Figure 3: Graphical illustration of spondylolisthesis with slipping of a vertebra

This picture shows the lumbar spine with olisthesis. The segment of L5 is slipped forward regarding the lower located segment of S1. Vertebral slippage is almost 25%, this equates to Meyerding grade I. (1995-2018, American Academy of Orthopedic spine surgeons AAOS, https://orthoinfo.aaos.org/en/diseases--conditions/adult-spondylolisthesis-in-the-low-back/ 30.04.2017)

Degenerative SL results from degenerative processes of the intervertebral disc and facet joints, without fractures. Through height reduction of the intervertebral disc, and relaxation of ligament the segment becomes unstable and dysfunctional. Meyerding categorizes the grades of SL from I to IV. This classification divides the superior endplate of the vertebra into four quarters and the grade of SL depends on the position of the posteroinferior corner of the vertebra above. Thus Meyerding grade I describes that the posteroinferior corner of the above located vertebra is slipped forward between 0-25%. Meyerding grade II goes from 26-50%, grade III from 51-75% and grade IV from 76-100%. If the above located vertebra is slipped forward for more than the full length of the lower vertebra it is often classified as Meyerding grade V or it is called spondyloptosis.

Through the sliding of vertebra and degenerative processes, the spinal canal is narrowed and thus SL often occurs together with SS. The stenosis goes from asymptomatic to huge lumbar radiculopathy, with symptoms as lumbago and claudicatio spinalis (Kast, 2009).

1.3.4 Diagnostic procedures

Despite much progress in spinal surgery and the help of imaging techniques, providing proper indications in spinal surgery is still very challenging.

The approach for an accurate treatment indication in spinal pathologies, is based on good and detailed anamnesis, clinical examination and imaging techniques.

Anamnesis should focus on quality and localization of radiculopathy, recent trauma or infection and psycho-social factors.
Clinical examination looks at eased muscle strength, paralyses, loss of function, reflexes, and straight-leg-tests as Lasègue's sign (Deutsche Gesellschaft für Neurologie, 2012).
During clinical examination and anamnesis, it is important to pay attention to risk factors, so called "red flags" (Arzneimittelkommission der deutschen Ärzteschaft (AkdÄ), 2007). Those red flags, as listed in *Table 1*, are warning signs for specific causes of back pain and are considered as absolute indications for surgery. When patients show these symptoms, they need surgery as soon as possible in order to avoid major irreversible neurological deficits.

Table 1:"Red flag" symptoms indicating urgent surgery

Symptoms	Clinical diagnostics
Recent severe or minor trauma (in elderly people with osteoporosis)	X-ray, MRI
Tumor/ infection (B-symptoms: fever, unintentional weight loss, night sweat)	X-ray, MRI, CT, scintigraphy, blood examination
Cauda equina syndrome (loss of bowel/bladder function as incontinence and perianal, perineal hypesthesia) **Neurological deficit** (palsy, paresthesia) of the lower extremity **Complete loss of function and improvement of pain** ("death of nerve root")	MRI, CT

This table lists red flag symptoms which absolutely indicate urgent surgery. On the right sight different diagnostic methods for diagnostic clarification are listed. Magnetic resonance imaging (MRI), Computed tomography (CT). (modified from Arbeitsgemeinschaft der Wissenschaftlichen medizinischen Fachgesellschaften, 2010)

Imaging techniques include for example X-ray, magnetic resonance imaging (MRI), computed tomography (CT), and myelography. Imaging tests are often used for patients with chronic lumbar radiculopathy to identify degenerative changes which cause specific LBP.
Already in early adulthood it is possible to recognize anatomical derangements as herniated disc, bulging disc, degenerative disc, and stenosis. It can be found in both symptomatic and asymptomatic patients, thus sometimes it is impossible to determine if those anatomical abnormalities cause the pain or not (Deyo, 2002; Boden, Davis, Dina, Patronas, & Wiesel, 1990; Wiesel, Tsourmas, Feffer, Citrin, & Patronas, 1984). According to Deyo (2002), this kind of anatomic derangements without symptoms or other clinical findings seem to be incidental,

and therefore without a clear symptomatology, they can be considered as inconsequent and irrelevant.
In general, imaging tests should be performed for patients with chronic lumbar radiculopathy and patients with acute radiculopathy and red flag symptoms. According to some studies, patients with acute LBP but without red flag symptoms should not undergo imaging (Shehaan, 2010; Koes, van Tulder, & Thomas, 2006).
Based on the results from anamnesis, clinical examination and imaging tests, it is now possible to weigh up possible therapies. For example, in the presence of red flag symptoms, the clear absolute indication for immediate surgery is indicated.
American and German clinical guidelines recommend surgery as relatively indicated if intense conservative treatment over more than six weeks is not efficient and clinical symptoms as well as imaging tests correlate with nerve root compression without regression of pain (North American Spine Society, 2011-2012-2014; Deutsche Gesellschaft für Orthopädie und orthopädische Chirurgie, 2017). Especially for those cases, indications in spinal surgery still vary widely.

1.4 Treatment possibilities of common spinal pathologies

Due to LBP's high prevalence, adequate treatment is of particular importance. The difficulty of indicating the correct treatment is that there are many different conservative and surgical treatment options. In addition, the scientific evidence was very contradictory until a few years ago. The different conservative and surgical treatment possibilities, which were also selectable in our survey, are now explained in the following.

1.4.1 Conservative treatment

According to the American and German national disease guidelines patients with longstanding pain, but without red flag symptoms or radiculopathy should be treated conservatively (Clinical Guidelines Committee of the American College of Physicians, 2017; Deutsche Gesellschaft für Neurologie, 2012).
Conservative treatment is based on interdisciplinary therapy regarding a biopsychosocial model with health education, movement and behavioral therapy, physical measures such as physiotherapy with back exercises, infiltrations, and pharmacotherapy. Over the last decades many studies have shown that monotherapies are less effective than a combination of different conservative approaches. These physical, psychological and educational components are combined in the multi- or interdisciplinary treatment approach for chronic LBP (Kamper, et al., 2014).

Physical approach usually includes encouragement of physical activity, movement exercises and physiotherapy. It is generally accepted that physiotherapy and continuing ordinary activities improve LBP and lead to a more rapid recovery (Malmivaara, et al., 1995). More recent studies show that stabilizing exercises, manipulative treatment, and specific individual treatment programs with well-informed patients are even more successful than normal physiotherapy alone (Niemistö, et al., 2003).

Adding of educational and behavioral components to physical approaches of conservative treatment is important. This includes being informed about LBP, learning about behavioral changes and getting instructions for a healthy lifestyle. A Cochrane review found moderate evidence that a greater relief of pain and better functional status was reached when educational and behavioral components were added to the usual conservative treatment (Ostelo, et al., 2005).

In addition to those conservative approaches, patients with chronic pain should consider ergotherapy, progressive muscle relaxation (PMR), and psychotherapy, because often back pain is caused by psychological factors such as stress (van Tulder, Koes, & Malmivaara, 2006). Especially for patients suffering from chronic LBP ergotherapy, physical conditioning as a return to work strategy, has shown to be successful (Schaafsma, et al., 2013).

As aforementioned, another approach to control patients' pain is the usage of pharmaceuticals. Pharmacotherapy should be used according to the WHO analgesic ladder in acute pain situations and it is considered as a supportive therapy. Studies show that nonsteroidal anti-inflammatory drugs (NSAID) are effective for acute pain situations. They found no specific NSAID to be better than others. Paracetamol and selective cyclooxygenase-2 (COX-2) inhibitors tend to have less side effects (Roelofs, Deyo, Koes, Scholten, & van Tulder, 2008). In some cases, co-analgesics such as antidepressants might improve pain reduction but show no influence in functioning (Staiger, Barak, Sullivan, & Deyo, 2003).

Beside the named approaches, also epidural injections are used to reduce patients' pain. Unfortunately, there are various opinions about its effectiveness. Some studies at least agree on a short time relief of pain when using epidural injections for patients suffering from chronic LBP (Cohen, Bicket, Jamison, Wilkinson, & Rathmell, 2013; Brown, 2012).

Surgical treatment for patients with chronic pain and without radiculopathy seem not to be better than conservative treatment (Chou, et al., 2009).

1.4.2 Surgical treatment

If surgery is indicated in patients with DH, SS or SL, the aim is to improve sensorimotor deficit and the reduction of pain caused by the irritated and compressed nerve root. A distinction is made between pure decompression procedures and decompression procedures with additional stabilization, called fusion. The decompression procedures differ depending on the

extent of the removed structures (interlaminar windowing, hemilaminectomy, laminectomy). An additional stabilization must be performed when load-bearing joint parts are removed.
For each of the three most common degenerative conditions the aim is the same, but the pathoanatomical mechanism is different, thus also surgical techniques and approaches can vary. For each patient, the operating surgeon should consider the appropriate surgical technique according to the symptoms, affections and condition of the patient while applying their know-how, and experience. American (North American Spine Society, 2011-2012-2014) and German national disease guidelines (Deutsche Gesellschaft für Neurologie, 2012) recommend following surgical therapies for lumbar radiculopathy caused by degenerative pathologies:

Microsurgical sequestrectomy and/or nucleotomy with interlaminar fenestration (ILF):
Herniated parts of lumbar intervertebral disc, or a sequester, are removed through an interlaminar window and posterior approach. According to different studies sequestrectomy has a slightly better outcome than microdiscectomy (Ran, et al., 2015; Fakouri, Patel, Bayley, & Srinivas, 2011; Schick & El Habony, 2009). The advantage for microsurgery is better outcomes and lower complication rates, less trauma, and fewer blood loss. If necessary, laminotomy, a partial removal of the vertebral arch called lamina, can be performed in order to gain a better view and better decompression of the nerve (Mayer, 2006).

Laminectomy/Hemilaminectomy:
Laminectomy means removal of whole laminae and spinous process of a vertebra. Hemilaminectomy is the removal of one lamina, while the other side remains. With laminectomy/hemilaminectomy more space for the nerve roots and thus decompression is possible and infradiscal or supradiscal prolapses or herniations are reachable, but it is a more invasive intervention (Obernauer & Thomé, 2015). Laminectomy is often performed to the opposite side of the access way and thus called “undercutting”.

Endoscopic interventions:
Endoscopic interventions originate in the lumbar spine and are not a novel concept. The first arthroscopic view of a disc was described by Forst and Hausmann in 1983 and the first endoscopic nucleotomy was performed by Kambin in 1988 (Forst & Hausmann, 1983; Kambin, Nixon, Chait, & Schaffer, 1988). It is mostly used in patients with DH and for nucleotomy with non-sequestered prolapse. Although this approach is minimally invasive and has clinical benefits, the development was very slow due to unfamiliarity with the technique and lack of expertise. Nowadays, initial studies investigate its efficacy and compare it to other techniques, so that endoscopic interventions grow in relevance (Anichini, et al., 2015).

Stabilization and decompression:

In case of destructed vertebral body, SL, or spondylodiscitis, stabilization should be performed. Stabilization results from titan screws positioned in the vertebral bodies, which are connected with titan bars to the upper and lower titan screws. Stabilization, also named spondylodesis, can be static, without any movement possibility in the affected segments left or dynamic with some rest movement in the segments (Guigui & Chopin, 1994).

Since neurological deficits are common for SL, decompression of the irritated nerve root should be performed. The most common surgical approach when performing decompression is a posterior approach with a laminectomy or hemilaminectomy. In cases of SL, stabilization is often added to decompression to avoid posterior instability (Ghogawala, et al., 2016).

1.5 Current level of evidence for common spinal pathologies

This work, as well as the current state of the art listed below, always refers to the case of a relative indication of surgery. This means that one speaks of patients with chronic LBP but without red flag symptoms where a conservative therapy was tried over several weeks without significant improvements.

1.5.1 State of the art for lumbar DH

The current state of the art for lumbar DH is that one can do surgery, but not has to. Therefore it can be treated conservatively or surgically. According to Rothoerl et al. (2002), in general, conservative treatment should be performed for up to two months on patients without red flag symptoms. Without improvement of symptoms, surgery should be considered afterwards. Many high-quality studies therefore compare the outcome of surgical treatment to a continuation of conservative treatment for patients suffering from lumbar DH. The Spine Patient Outcome Research Trial (SPORT), for example, conducted their studies at 13 sites across the US for more than 5 years, and included 2,500 well-selected patients. They randomly selected their participants into two groups, one underwent surgery and the other one was treated conservatively (Weinstein J. , et al., SPORT: Spine patient outcomes research trial, 2006-2007). As surgical therapy, they performed open discectomy with examination and decompression of the nerve root. As conservative treatment active physical therapy, education/counseling, infiltrations, and NSAIDs are used. They show faster and better improvements in pain and function in their surgically treated group over a 2-year period (Weinstein J. , et al., 2006). Results are maintained in their follow-up studies after four years and eight years (Weinstein, et al., 2008; Lurie J. , et al., 2014).

Beside the SPORT trial, the Maine Lumbar Spine Study also compared surgical and conservative treatments for patients suffering from lumbar DH. In accordance to the results of SPORT they also show greater improvement in function and more satisfaction in the surgically treated group than patients treated conservatively (Atlas, et al., 1996). Results are also maintained with different follow-up studies over a period of five and ten years (Atlas S. , Keller, Chang, Deyo, & Singer, 2001) (Atlas S. , Keller, Wu, Deyo, & Singer, 2005).
In contrast to those major studies "Leiden-The Hague Sciatica trials" report faster pain relief in the surgery group only for the first year (Peul, et al., 2007). Although performed surgical and conservative treatment was equivalent to the other studies their follow-up results show no significant differences between surgical and conservative treatment over a period of two and five years (Peul, van den Hoult, Brand, Thomeer, & Koes, 2008; Lequin, et al., 2013).

1.5.2 State of the art for lumbar SS

The state of the art for lumbar SS is that one should do surgery. For lumbar SS major trials show significantly better outcomes, regarding pain, function, and satisfaction for patients undergoing surgery than conservative treatment. As surgical treatment, laminectomy as decompressive intervention is performed. Conservative treatment includes active physical therapy, education/counseling, infiltrations and NSAIDs (Weinstein J. , et al., 2008). Their results of favorable surgical therapy are maintained over a period of four and eight years (Weinstein J. , et al., 2010; Lurie J. , et al., 2016).
Recent studies compare decompression surgery alone versus decompression surgery plus fusion for patients with lumbar SS. The addition of fusion showed no significant advantages and is thus considered as overtreatment (Försth, et al., 2016). Consequently, current literature recommends decompression surgery without fusion for patients with lumbar SS when initial conservative treatment is not sufficient.

1.5.3 State of the art for lumbar SL

The state of the art for lumbar SL, when performing our survey was to perform decompression plus fusion. Major studies of lumbar SL, such as the aforementioned SPORT trial, compared the outcomes of surgical and conservative treatment. As surgical intervention decompressive laminectomy with or without fusion is performed. Conservative treatment again includes active physical therapy, education/counseling, infiltrations, and NSAIDs. Patients treated surgically show greater improvement in pain and function as compared to patients treated conservatively over a 2-year period (Weinstein, et al., 2007). Results are maintained over a period of four years (Weinstein, et al., 2009).

In recent years, the question whether fusion is really necessary in addition to decompression has increasingly arise. Different studies investigate this topic until now. Results of some older (Herkowitz & Kurz, 1991; Bridwell, Sedgewick, O'Brien, Lenke, & Baldus, 1993) and more recent studies (Martin, et al., 2007; Ghogawala, et al., 2016) favor decompression surgery, followed by fusion of the unstable segments over decompression surgery alone. In contrast there exist studies which clearly favor decompression alone (Chang, Fujisawa, Tsuchiya, Oya, & Matsui, 2014; Rampersaud, et al., 2014).

Especially Ghogawala shows only a slightly greater, but clinically meaningful, outcome in physical health-related quality of life over a longer period of two, three, and four years for patients treated with decompression surgery plus fusion (Ghogawala, et al., 2016).

Summing up, the issue whether to fuse or not is not yet finally resolved.

1.6 Aim of the study and research question

The socioeconomic importance of LBP is commonly known. Despite the above- mentioned scientific literature, which shows clear level I evidence for the treatment indication of most common spinal pathologies, indications in spinal surgery still vary widely. Consequently, this leads to inadequate treatment of LBP, chronification of pain, and repeated medical consultations.

Therefore, the aim of this work is to investigate indications in spinal surgery and to identify possible reasons for the variation in the treatment indication.

Patients with spinal problems concern physicians from two different medical specialties, neurosurgery and orthopedic spine surgery. Until now, there is a lack of empirical evidence regarding differences in decision-making between neurosurgeons and orthopedic spine surgeons for lumbar spinal pathologies in Germany. This leads to our first hypothesis: Medical specialty affiliation does not affect the indication in spinal surgery.

Unattached to their specialty, physicians often must decide whether to treat own relatives or not. Despite recommendations that physicians should treat family members only for minor conditions, it is even common when these family members face major problems. Up to now, only a few studies have investigated how or if personal emotional involvement of the physician influences its decision-making. Nevertheless, there is still a lack of scientific evidence regarding personal emotional involvement in spinal surgery. This leads to our second hypothesis: Personal emotional involvement does not impact the treatment indication in spinal surgery.

At the time of EBM, it has not yet been investigated to what extent a different experience influences the treatment indication, especially if there is clear level I evidence. Therefore, this leads to our third hypothesis: The experience of board-certified surgeons does not influence the indication in spinal surgery.

Summing up, this work is one of the first attempts to investigate the association of decision-making in spinal surgery with medical specialty, personal emotional involvement and experience.

Furthermore, this work should contribute to improve the treatment indication of specific LBP. It should help to understand where different medical approaches derive from and it can contribute to spread the knowledge about level of evidence treatment in spinal surgery.

2. MATERIALS AND METHODS

2.1 Study design

We decided to collect the data nationwide to ensure a representative number for German physicians and to avoid regional influence factors.

For the INDIANA (**Indi**c**a**tions in Spi**nal** Surgery) trial, we created an internet-based questionnaire with three different patient cases regarding common spinal pathologies for which there is clear level of evidence regarding their treatment indication. German neurosurgeons and orthopedic spine surgeons were asked nationwide to fill in this questionnaire and to indicate their treatment for those patient cases. With the investigation of those two medical specialties, we were able to gain data to answer the first research question, namely if the participants indicate the “state of the art” therapy and if there are differences between both specialties regarding their decision-making.

For the second research question, we created personal relation between the examining physician and the advice-seeking patient. To create this personal emotional involvement, we classified participants randomly into two groups, a patient group (PG) and a relative group (RG). In the PG, the person seeking medical advice was a regular patient. Instead, in the RG, there was a well-known relative seeking for medical advice. None of the two groups was informed about the existence of the other, in order to avoid biasing physicians’ decision-making.

To investigate further influencing factors or predictive variables, such as experience, each group consisted equally of physicians with more and with less than ten years of board certification.

2.2 Ethical approval

The study protocol of the INDIANA survey was created in accordance to the ethical principles of the Declaration of Helsinki. The ethical committee of the Technical University of Munich approved this protocol under the reference number 5812/13. During a contact phone call, we asked our participating physicians orally for their agreement to participate. Before filling in the questionnaire they again gave consent about their participation in order to proceed with the study.

2.3 Selection of participants

For the INDIANA survey we included neurosurgeons and orthopedic spine surgeons who fulfilled our following inclusion criteria:

- Being a board-certified consultant for neurosurgery or orthopedics;
- Active employment in German hospitals or doctor's offices with focus on spinal pathologies; and
- Active performance of spinal surgeries, thus specializing in spinal surgery.

Resident physicians and board-certified orthopedic spine surgeons who just focus on traumatic spinal pathologies and board-certified physicians who do not perform surgeries have been excluded from our study.

We searched for possible candidates, or more precisely physicians who were eligible for participation according to our inclusion criteria, on websites of university hospitals and large hospitals.

We scaled our potential candidates in lists, according to their specialty, years of board certification and working hospital or doctor's office. Due to this stratification of our participants, we achieved homogeneous subgroups that fulfill the same conditions and were subject to the same influencing factors. Those subgroups were randomly assigned to the group of PG or RG. Their contact details, including their phone number and e-mail address were added. Each of the participants was assigned an access code according to the group classification (PG and RG) and years of board certification. It was very important that each group does not know about the existence of the other. Thus, every participant from the same hospital or doctor's office was scaled into the same group, PG or RG, as the participating colleagues. With those lists we could keep the overview of which candidates were scaled into which groups and if they had already replied to the questionnaire completely. *Figure 4* shows the assignment of participants to the subgroups in the questionnaire.

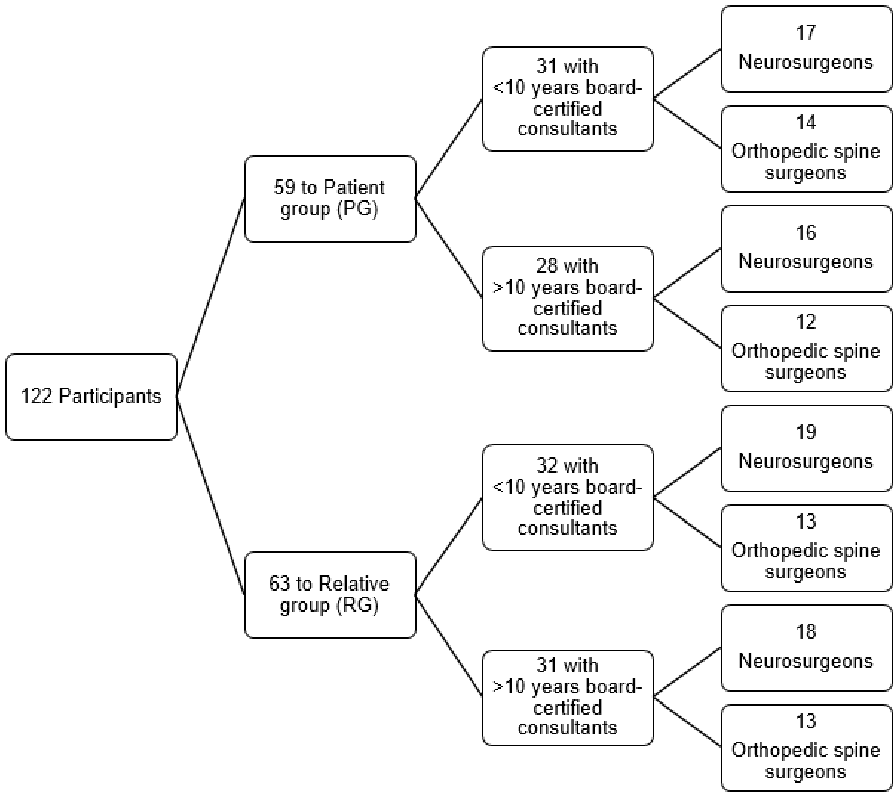

Figure 4: Assignment of participants

This figure shows the precise distribution of our 122 participants to the subgroups of patient group and relative group. Additionally, it is shown how the participants were distributed regarding their years of experience and medical specialty.

We created a personalized access code for each participant. With this code it was possible to enter the website of our questionnaire and to proceed with replying our questions.

2.4 Structure of the questionnaire

We created an online-based questionnaire because our participants were from different parts of Germany and we wanted to design it participant-friendly. The access to the questionnaire was possible via personal login at any time.

The questionnaire consisted of five webpages and access was only possible with the personalized code.

Fragebogen INDIANA

Sehr geehrte Studienteilnehmer,

in der Studie, über die wir Sie informieren möchten, wird untersucht, welche Unterschiede es in der Indikationsstellung bezüglich der operativen Therapie häufiger Wirbelsäulenerkrankungen gibt.
Für Sie würde die Teilnahme an dieser Studie bedeuten, dass Sie die folgenden Fragen entsprechend Ihrem üblichen klinischen Vorgehen beantworten.

Alle im Rahmen dieser Studie erhobenen studienbezogenen Daten werden entsprechend der gesetzlichen Bestimmungen vertraulich behandelt. Die wissenschaftliche Auswertung der Daten erfolgt pseudonymisiert, d.h. ohne Angabe Ihres Namens. Die korrekte und vollständige Aufzeichnung aller Daten ist besonders wichtig für den Forschungszweck und dient damit auch der Sicherheit zukünftiger Patienten. Die Ergebnisse der Studie werden in Form einer wissenschaftlichen Arbeit veröffentlicht. Die Anonymität der Studienteilnehmer bleibt selbstverständlich auch in diesem Fall gewahrt.
Die Fragebogendaten werden vom Dienstleister (SCHRICK-DESIGN) ausschließlich ohne die jeweiligen Zugangscodes den Kontaktpersonen/Betreuern zur Verfügung gestellt. Somit kann bei der Auswertung keine Verbindung zwischen Fragebogen und Teilnehmer hergestellt werden.

Die Teilnahme an der Studie ist freiwillig und kann von Ihnen jederzeit widerrufen werden. Für Rückfragen stehen wir selbstverständlich jederzeit zur Verfügung.
Kontaktperson für diese Studie ist:
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- Nico Sollmann (Tel.: 089-4140-7671, E-Mail: nico.sollmann@lrz.tum.de).

Am (Datum auswählen) wurde ich durch Dres. Behr/ Preuß/ Krieg über Wesen, Bedeutung und Tragweite der klinischen Prüfung, sowie über erwartete Wirkungen und absehbare Risiken der hier geplanten Prüfung unterrichtet. Ich habe die oben stehende Teilnehmerinformation gelesen und verstanden und alle meine Fragen klären können. Eine Kopie der Teilnehmerinformation und der Einverständniserklärung können von mir ausgedruckt werden. Ich nehme freiwillig an dieser Prüfung teil und weiß, dass ich mein Einverständnis jederzeit ohne Nachteile für mich widerrufen kann.

Figure 5: First part of the questionnaire

This picture shows the first part of our questionnaire in German. It contains a short explanation of the study and contact details for questions and problems. In the last part, the participant had to select the date and give his general consent to participate in the study.

The first part of the questionnaire, shown in *Figure 5*, explained the study shortly and informed the participants about anonymization. Again consent to participate was asked.
The next part consisted of questions about personal experience and training background. *Figure 6* shows this part of the questionnaire.

Allgemein:

1. Wie lange sind Sie bereits Facharzt?
 ___________(Anzahl Jahre)

2. Wie viele Wirbelsäulen-OPs haben Sie ungefähr bereits durchgeführt?
 Insgesamt: _________ (Anzahl OPs)
 In den letzten 5 Jahren im Durchschnitt pro Jahr:
 ___________________ (Anzahl OPs)

3. Wie viele der entsprechenden Krankheitsbilder haben Sie bislang ungefähr operativ in den letzten 5 Jahren behandelt?
 - BSV (Bandscheibenvorfall):_____________(OPs/Jahr)
 - SKS(Spinalkanalstenose):______________(OPs/Jahr)
 - Spondylolisthese:_____________________(OPs/Jahr)

4. Wie häufig lesen Sie aktuelle wissenschaftliche Literatur?
 __________________ (Artikel/Monat)

Figure 6: General part of the questionnaire: training background and experience

This picture shows general questions about training background and experience. For example, participants were asked about the number of years as a board-certified specialist, the number of surgeries performed and the frequency of reading scientific articles.

In this part the participants had to announce their overall number of performed spinal surgeries and regarding the last five years, a mean number of spinal surgeries performed per year. Another question referred to specific surgeries performed within the last five years on patients with DH, SS and SL. Due to the answers of these questions we were also able to see if our participant specialties are comparable to each other. This was important in order to minimize biasing of decision-making by different training background.

In order to compare the extent to which experience influences the treatment indication within each medical specialty group, we compared the indications of physicians with less than ten years of board certification, to those of physicians with equal or more than ten years of board certification.

To prevent confounding of our results we explored potential predictive variables and potential confounder variables of our questionnaire. As potential predictive and confounding variables, we considered training background and experience of our participating physicians. As training background and experience, we considered the following parameters: years of being board-certified consultant, overall numbers of performed spine surgeries, numbers of performed spine surgeries for the last five years per year, numbers of spine surgeries performed regarding

DH, SS and SL in the last five years, numbers of scientific literature read per month, and own relative counseled.

In addition, we tried to exclude confounding our results regarding decision-making and specialty, and decision-making and personal emotional involvement by also using those variables listed above.

The next part of the questionnaire included specific questions about our degenerative spinal pathologies pictured with three patient cases (case A, case B, case C in *Figure 7*).

Our patient cases are based on the three most common degenerative spinal pathologies, namely lumbar DH, SS, and SL.

Each patient case included personal information about the patient, gained from anamnesis including the patients' age, Body Mass Index (BMI), period of symptoms and localization, previous treatment, and intensity of pain, measured with VAS. It is mentioned, if paresis has already occurred and if there have been problems with the bowel or bladder function. Each patient case was illustrated with MRI images in sagittal and axial plane. Also, for the case of lumbar SL, a functional X-ray image with lateral view was demonstrated. The different images created better and more realistic conditions. *Figure 7*, shows the three patient cases:

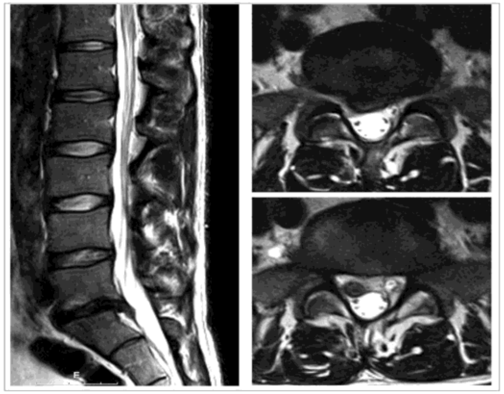
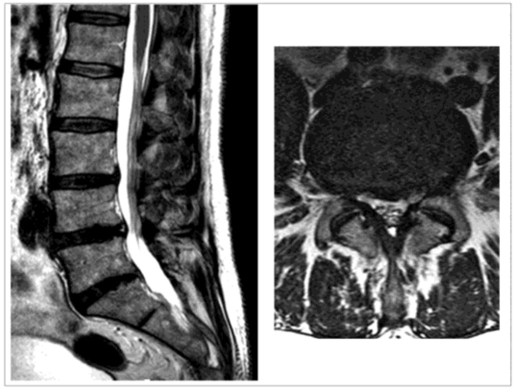
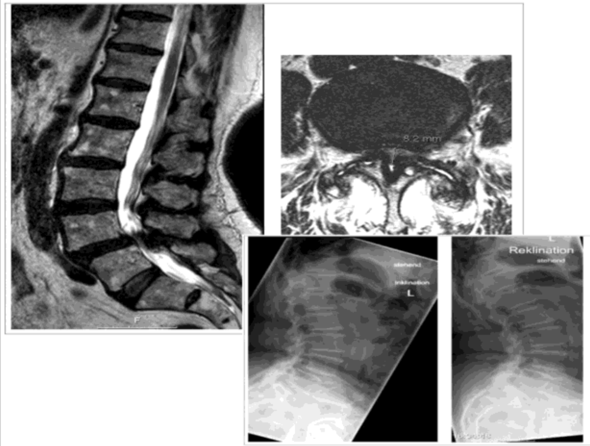
(A) lumbar disc herniation	(B) lumbar spinal stenosis	(C) lumbar spondylolisthesis
		
– age: 42 years, BMI: 26 – symptomatic since 9 weeks – oral analgesics, comparable recurrent symptoms within the last 6 months – sciatica with radiation into dorsal upper and lower leg and lateral foot – VAS leg: 6/10, VAS back: 3/10 – paresis plantar flexors: BMRC 4+/5 right-sided, positive Lasègue test (30 degrees), no bladder-colon disturbances – MRI: disc herniation L5/S1 right-sided – X-ray: no listhesis	– age: 65 years, BMI: 29 – symptomatic since 9 months – oral analgesics, occasional physiotherapy – claudicatio spinalis: walking distance 500 m, sitting down / lumbar flexion leads to improvement of smyptoms – sciatica during activity with radiation into lateral upper and lower leg and dorsum of foot – VAS leg: 6/10 (strain-related), VAS back: 3/10 – nearly no symptoms during rest or sitting – no paresis during rest, no positive Lasègue test, no bladder-colon disturbances – MRI: concentric osteo-ligament stenosis L4/5 – X-ray: no listhesis	– age: 66 years, BMI: 29 – symptomatic since 10 months – oral analgesics, occasional physiotherapy – claudicatio spinalis: walking distance 300 m, lumbar flexion leads to improvement of smyptoms – sciatica during activity with radiation into lateral upper and lower leg and dorsum of foot – VAS leg: 7/10 (strain-related), VAS back: 6/10 (strain-related), ratio VAS leg : back 3 : 10 during rest – no paresis during rest, no positive Lasègue test, no bladder-colon disturbances – MRI: pseudo-spondylolisthesis Meyerding I with consecutive stenosis L4/5 – X-ray: increase of listhesis

Figure 7: Three different patient cases of our INDIANA survey

This picture shows the different patient cases for (A) lumbar disc herniation, (B) lumbar spinal stenosis, and (C) lumbar spondylolisthesis. Each case includes radiographic images as MRI and/or X-ray slides and a short anamnesis. Body mass index (BMI), Brithish Medical Research Council (BMRC), Magnetic resonance imaging (MRI), Visual analogue scale (VAS). Reused by permission from ***Springer Customer Service Centre GmbH****:* ***Springer Nature****, ACTA NEUROCHIRURGICA, Association of decision-making in spinal surgery with specialty and emotional involvement—the Indications in Spinal Surgery (INDIANA) survey, Sollmann, N., Morandell, C., Albers, L. et al., ©* ***Springer-Verlag GmbH Austria, part of Springer Nature,****2018*

Regarding the age of our patients we closely referred to the mean ages from the patient cases of the SPORT trials (Weinstein J. , et al., SPORT: Spine patient outcomes research trial, 2006-2007). For each of the three patient cases the same four questions, as shown in *Figure 8* and *Figure 9,* had to be answered*.* At the beginning of each patient case, participants had to answer if they indicate conservative or surgical treatment. Depending on this initial answer, different subquestions regarding conservative or surgical treatment possibilities were shown. Then, the participant had to decide which of the treatment possibilities he favors, if his decision was based on gut feeling/experience or rather scientific evidence, and in percentage how sure he was about his decision. Last question of each patient case was, if the participant already had to counsel a relative with certain pathology.

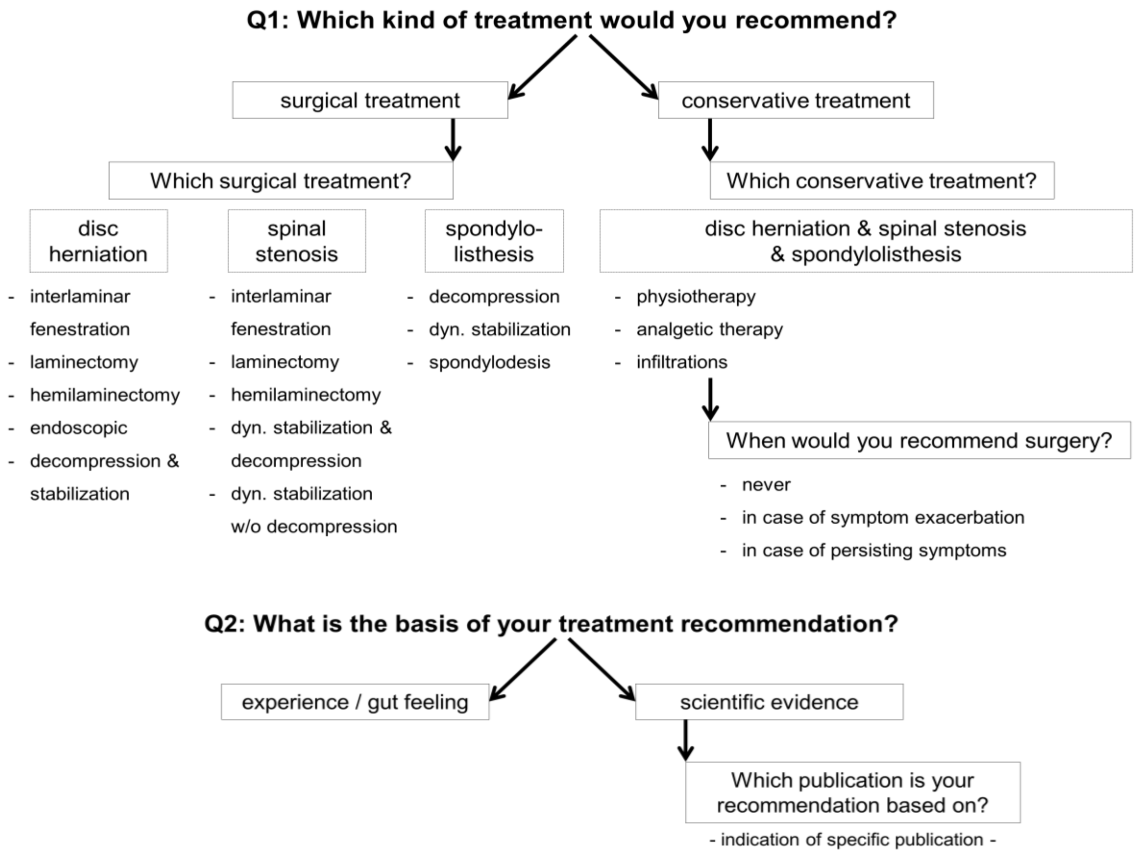


Figure 8: Questions and answers for patient cases - part 1

This figure depicts our questions and possible answers for our participants. First the participant had to choose between surgical or conservative treatment. Depending on this answer different conservative or surgical treatment possibilities were selectable. Conservative possibilities were the same for all patient cases, but surgical possibilities were different for each patient case. Only one answer was possible to choose. For question 2 the participant had to choose between gut feeling/experience or scientific evidence being the basis of his decision. When selecting scientific evidence, it was possible to write down a certain publication. Reused by permission from ***Springer Customer Service Centre GmbH:*** ***Springer Nature****, ACTA NEUROCHIRURGICA, Association of decision-making in spinal surgery with specialty and emotional involvement—the Indications in Spinal Surgery (INDIANA) survey, Sollmann, N., Morandell, C., Albers, L. et al., ©****Springer-Verlag GmbH Austria, part of Springer Nature,*** *2018*

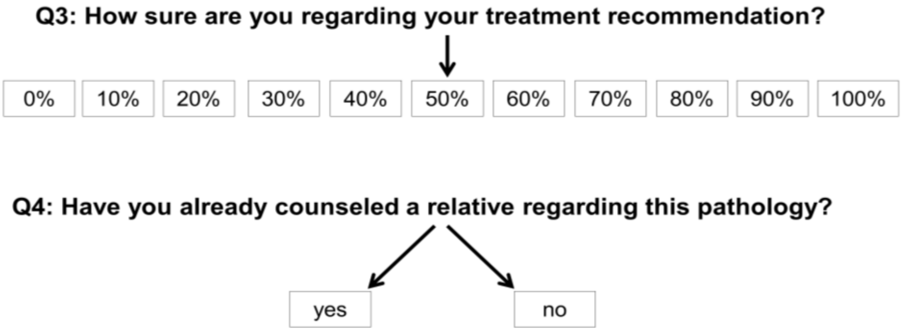


Figure 9: Questions and answers for patient cases – part 2

This figure also depicts our questions and different answer possibilities. For question 3 the participant had to name how certain he was with his answer. Answers were given as percentages from 0% (totally uncertain) to 100% (most certain) with increments of 10. The final question concerned if the participant already had to counsel a relative suffering from this pathology. Reused by permission from ***Springer Customer Service Centre GmbH****:* ***Springer Nature****, ACTA NEUROCHIRURGICA, Association of decision-making in spinal surgery with specialty and emotional involvement—the Indications in Spinal Surgery (INDIANA) survey, Sollmann, N., Morandell, C., Albers, L. et al., ©* ***Springer-Verlag GmbH Austria, part of Springer Nature,*** *2018*

As explained before our participants were scaled into two major groups, the PG and RG. The questionnaire was the same for both groups, except the advice-seeking person was different. The PG had to name their treatment indication for patients, as they would in their daily work. Thus no personal involvement was created. The other group, RG, had to treat a relative as patient in our cases, in order for there to be personal emotional involvement between the physician and the patient. Physicians of the RG had to name a relative who fitted the best to the given patient age for each case before answering the questions, demonstrated in *Figure 8* and *Figure 9*. They could choose between their own wife/husband, mother/father, sister/brother, daughter/son, aunt/uncle, nice/nephew, sister-/ brother-in law or cousin, who was seeking medical advice. Physicians of the RG thus had to name their indication for the chosen relative. It was very important that neither of the two groups knew about the existence of the other in order to prevent biased populations.

After responding to all questions of a patient's case, the respondent was not allowed to return to prior questions. For each question only one answer was possible to choose from. Depending on the answers different subquestions followed.

2.5 Recruitment of participants and data acquisition

After creating the questionnaire and the lists with potential candidates and their contact details, like phone numbers and email addresses, we called those potential candidates by phone. The INDIANA survey was shortly explained, and we checked our inclusion criteria with the

candidates during the telephone conversation. They were asked for their approval to participate and incoming questions were replied. When physicians decided to join our survey, further information and details, the link to our online questionnaire and the personalized access code, were sent by email. Before sending the email, we checked the participants' assignment to the subgroups (PG, RG) and the link to the study. Finally the personalized access code was also rechecked and had to concur with our personal-related code of the participants list.
After receiving our email, the participants were able to log in at our questionnaire and to complete it.
Every data was anonymized, and even during analysis no data could be linked to a specific participant's name. We could only see if personalized codes were already in use and if the questionnaire had been filled. If the physicians did not participate after three weeks we sent a reminder with log in data and personalized access codes. Reminding emails have been sent for at least three times each three weeks, so that participants had enough time to eventually complete the online questionnaire.
Process time to complete the whole questionnaire required ten to fifteen minutes.
After one year of data acquisition we had a total number of 155 physicians who received their access codes. 122 participants replied completely to the whole questionnaire, which formed the basis of our survey data.

2.6 Data evaluation and statistical analyses

We counted the responses of neurosurgeons and orthopedic spine surgeons as absolute numbers and frequencies. For each specialty we calculated response rates. To assess potential differences between the specialties we then performed Chi-squared tests. The first part of our questionnaire contained questions referring to the training background and experience of our participants. With those answers we counted absolute numbers and relative frequencies again. Thus we were able to calculate, means ± standard deviation (SD), medians and ranges. For those ordinal-scaled results we used Mann-Whitney U tests to assess differences in training background between the two medical specialties.
The second part contained the three patient cases. Physicians could choose between different treatment possibilities and had to name their favorite indication. In order to gain comparable treatment categories we assigned the different answers for each case according to the following classification shown in *Table 2.*
With these comparable categories we were able to count our results and to compare decisions from neurosurgeons with orthopedic spine surgeons and PG with RG. We calculated odds ratios (ORs), 95% confidence intervals (CIs), and compared the results by Chi-squared tests for each patient case.

For quantitative non-parametric data, such as comparing certainties in one owns decision between the specialties and between PG and RG, again the Mann-Whitney-U test was used.

Table 2: Allocation of answer possibilities to comparable subgroups

Patient cases	Treatment possibilities	
1. Lumbar disc herniation (DH)	Surgical treatment	Interlaminar fenestration (ILF)
		Laminectomy
		Hemilaminectomy
		Endoscopic
		Decompression & stabilization
	Conservative treatment	Physiotherapy
		Analgesics
		Infiltrations
2. Lumbar spinal stenosis (SS)	Level of evidence treatment	ILF
		Laminectomy
		Hemilaminectomy
	Overtreatment	Dynamic stabilization with or without decompression
	Undertreatment	Conservative treatment*
3. Lumbar spondylolisthesis (SL)	Level of evidence treatment	Dynamic stabilization
		Fusion
	Undertreatment	Conservative treatment*
		Decompression

This table shows the categorization of possible answers to comparable groups. For the case of lumbar DH we used two categories, surgical and conservative treatment, for comparison. For the lumbar SS case three categories, namely level of evidence treatment, overtreatment, and undertreatment were used. For the lumbar SL case we again used two categories, level of evidence treatment and undertreatment.
**Conservative treatment always includes physiotherapy, analgesics, and infiltrations and was the same for all three patient cases.*

Mann-Whitney-U tests and Chi-squared tests were performed with the program GraphPad prism (GraphPad Prism 6, La Jolla, CA, USA). For our trial we considered a p-value of $p<0.05$ as statistically significant.

We performed univariate regression analyses to assess if surgeons' training background and experience (professional experience, the number of spinal surgeries in career, the average annual number of spinal surgeries within the last 5 years, former consultation of own relatives, or the number of scientific publications read per month) predicted their decision-making and thus their treatment indication for each patient case. For this model, we used decision-making as the dependent variable and the aforementioned training background and experience variables as independent variables.

Other univariate logistic regression models were used to identify potential confounding of the results. We controlled for potential confounding by training background and experience for the associations of decision-making with both, specialty and personal emotional affection.

Regression analyses were performed with the statistical software R (R 3.1.0, The R Foundation for Statistical Computing, Vienna, Austria). For our univariate regression models ORs with 95% CIs were calculated. Variables with p-values under 0.1 in all regression models were considered as potential confounders.

3. RESULTS

3.1 Results of participation and enrollment

After finishing our data acquisition with contacting potential candidates by phone, 155 eligible physicians agreed to participate in our INDIANA survey. Of those 155 participants, 122 filled in the questionnaire completely. This number leads to a response rate of 78.7%.
33 physicians, equivalent to 21.3%, did not fill in the whole questionnaire or did not use their access code after several reminders. Without clarifying reasons, we considered them as drop-outs.
The next step was to assign our participants into balanced, comparable subgroups. We include 70 neurosurgeons (57.4%) and 52 orthopedic spine surgeons (42.6%) in our survey. Both groups of participants comprise physicians with more or less than 10 years of board-certified consultants. *Table 3* shows that the subgroups are balanced, also regarding years of board certification. Since the p-value of 0.9569 is not significant, we have no reason to assume differences between our two medical subgroups regarding their experience.

Table 3: Distribution of participants regarding medical specialty and years of experience

	Neurosurgeons	**Orthopedic spine surgeons**
< 10 years board-certified	36	27
≥ 10 years board-certified	34	25
p-value	0.9569	
OR	0.9804	
95% CI	0.4649-2.058	

This table shows how our two subgroups of neurosurgeons and orthopedic spine surgeons are structured. Both groups include participants with less and greater equal 10 years of board certification. Odds ratio (OR) and 95% confidence interval (CI) are calculated. To compare both subgroups, p-value is provided. No significant differences between those two groups could be demonstrated.

For our second research question we need to assign neurosurgeons and orthopedic spine surgeons to balanced subgroups, the PG and RG. As *Table 4* shows, the PG has 59 participants (48.4%), of which 33 are neurosurgeons (55,9%), and 26 are orthopedic spine surgeons (44.1%). The RG has 63 participants (51.6%) with 37 neurosurgeons (58.7%), and

26 orthopedic spine surgeons (41.3%) in it. Since the p-value of p=0.7548 indicates no statistical significance, we consider our subgroups of PG and RG to be equally balanced.

Table 4: Allocation of medical specialty to patient group (PG) and relative group (RG)

	PG	**RG**
Neurosurgeons	33	37
Orthopedic spine surgeons	26	26
p-value	0.7548	
OR	0.8919	
95% CI	0.4229-1.873	

This table shows the structure of our PG and RG subgroups. Both subgroups consist of neurosurgeons and orthopedic spine surgeons. Odds ratio (OR) and 95% confidence interval (CI) are calculated. To compare both subgroups, p-value is provided. No significant differences between both groups are revealed with statistical analyses.

3.2 Results of training background and experience

Since the medical subgroups, as well as our PG and RG, are numerically balanced, it is also important that the participants of each group have a comparable training background. Responses of the initial questions from the online survey are used to investigate training background and experience of our participants. The results in *Table 5* show that our groups of neurosurgeons and orthopedic spine surgeons are highly comparable regarding their training background. A significant difference is shown for the number of performed lumbar DH surgeries in the last five years per year. In this case, neurosurgeons performed significantly more surgeries than orthopedic spine surgeons. This is indicated by the p-value of p=0.0021. Instead, for all other numbers of performed surgeries, there are no significant differences between neurosurgeons and orthopedic spine surgeons.

When comparing the results of our less experienced subgroup (less than ten years of board certification) to those of the more experienced subgroup (greater equal 10 years of board certification) no statistically significant differences could be observed. This holds for both medical specialty groups and for all three patient cases.

However, we observe a minimal trend of indicating more level of evidence treatment in the group of physicians with less than 10 years of board certification for all three patient cases. More detailed results are presented under the respective patient case.

Table 5: Results of training background & experience between neurosurgeons and orthopedic spine surgeons

	Neurosurgeons	**Orthopedic spine surgeons**	**p-values**
Experience/ years of board certification (mean ± SD & ranges)	10.10 ± 7.21 (1-31)	9.69 ±7.57 (0-40)	0.6671
Number of spinal surgeries in career (mean ± SD & ranges)	1,758.43 ± 1,546.67 (50-7,000)	1,580.00 ± 1,327.77 (50-5,000)	0.5670
Number of spinal surgeries in the last 5 years per year (mean ± SD & ranges)	186.71 ± 176.69 (1-1,000)	192.54 ± 131.04 (1-600)	0.3505
Number of herniated disc surgeries in the last 5 years per year (mean ± SD & ranges)	71.54 ± 56.40 (0-300)	46.40 ± 46.26 (0-200)	**0.0021**
Number of spinal stenosis surgeries in the last 5 years per year (mean ± SD & ranges)	74.06 ± 63.19 (0-300)	56.87 ± 46.70 (0-200)	0.1640
Number of spondylolisthesis surgeries in the last 5 years per year (mean ± SD & ranges)	44.60 ± 52.47 (0-250)	42.46 ± 34.65 (0-150)	0.4046
Number of scientific articles read per month (mean ± SD & ranges)	9.73 ± 10.91 (1-60)	7.29 ± 5.59 (0-30)	0.7479

This table describes the training background and experience of our neurosurgeons and orthopedic spine surgeons. Experience is measured with years of board certification. Training background is calculated with exact numbers of performed surgeries in career, over the last 5 years, and regarding the certain spinal pathologies. Also the number of scientific articles read per month is calculated. For each parameter means, standard deviations (SDs), and ranges are calculated. P-values to compare neurosurgeons and orthopedic spine surgeons are provided. Significant differences are displayed in bold. The statistical evaluation shows that both groups are comparable.

Table 6 shows the results for training background and experience within the PG and RG. No significant differences between those two groups could be shown.

Table 6: Results of training background & experience between patient group (PG) and relative group (RG)

	PG	RG	p-values
Experience/ years of board certification (mean ± SD & ranges)	9.85 ± 7.53 (0-40)	11.16 ± 7.25 (1-31)	0.8731
Number of spinal surgeries in career (mean ± SD & ranges)	1,553.73 ± 1,335.09 (50-5,000)	1,802.85 ± 1,552.53 (50-7,000)	0.3575
Number of spinal surgeries in the last 5 years per year (mean ± SD & ranges)	182.24 ± 166.29 (10-1,000)	195.71 ± 149.91 (1-1,000)	0.2938
Number of herniated disc surgeries in the last 5 years per year (mean ± SD & ranges)	57.77 ± 50.19 (0-230)	63.70 ± 53.68 (0-300)	0.5465
Number of spinal stenosis surgeries in the last 5 years per year (mean ± SD & ranges)	60,34 ± 52.82 (0-230)	72.72 ± 58.41 (0-300)	0.0881
Number of spondylolisthesis surgeries in the last 5 years per year (mean ± SD & ranges)	40.22 ± 44.24 (0-250)	46.94 ± 45.91 (0-250)	0.2815
Number of scientific articles read per month (mean ± SD & ranges)	9.02 ± 9.17 (0-60)	10.34 ± 7.65 (1-30)	0.3394

This table describes the training background and experience of our PG and RG. Experience was measured with years of board certification. Training background is calculated with exact numbers of performed surgeries in career, over the last 5 years, and regarding the certain spinal pathologies. Also the number of scientific articles read per month is calculated. For each parameter means, standard deviations (SDs), and ranges are calculated. P-values to compare PG and RG are provided. The statistical evaluation shows that both groups are comparable.

Table 7 compares neurosurgeons and orthopedic spine surgeons within the PG and the RG. The results of this table show that even when comparing both medical specialties within the RG, no significant differences in training background and experience could be found. When comparing neurosurgeons and orthopedic spine surgeons within the PG we have two significant differences. In the last five years neurosurgeons performed significantly more lumbar DH and lumbar SS surgeries than orthopedic spine surgeons. Those results are indicated by p-values of p=0.0075 for lumbar DH and p=0.0203 for lumbar SS.

Table 7: Results of training background & experience of neurosurgeons and orthopedic spine surgeons respecting assignment to PG and RG

	Patient group (PG)			**Relative group (RG)**		
	Neuro-surgeons	Orthopedic spine surgeons	p-value	Neuro-surgeons	Orthopedic spine surgeons	p-value
Experience/ Years of board certification (mean ±SD & ranges)	10,58 ± 7.11 (1-29)	8.92 ± 8.07 (0-40)	0.2780	9.68 ± 7.36 (2-31)	10.46 ± 7.10 (1-25)	0.5709
Number of spinal surgeries in career (mean ± SD & ranges)	1,762.42 ± 1,439,86 (110-5,000)	1,288.85 ± 1,202.12 (50-4,000)	0.1484	1,754.68 ± 1,655.95 (50-7,000)	1,871.15 ± 1,405.36 (50-5,000)	0.5020
Number of spinal surgeries in the last 5 years per year (mean ±SD & ranges)	184.91 ± 182.60 (22-1,000)	178.85 ± 145.58 (10-600)	0.9424	188.32 ± 173.77 (1-1,000)	206.23 ± 115.96 (1-400)	0.2046
Number of herniated disc surgeries in the last 5 years per year (mean ±SD & ranges)	67.73 ± 48.51 (10-230)	45.12 ± 52.32 (0-200)	**0.0075**	74.95 ± 63.08 (0-300)	47.69 ± 40.30 (0-150)	0.0664
Number of spinal stenosis surgeries in the last 5 years per year (mean ±SD & ranges)	72.06 ± 55.79 (0-230)	45.46 ± 49.04 (0-200)	**0.0203**	75.84 ± 69.86 (0-300)	68.27 ± 42.12 (0-150)	0.7252
Number of spondylolisthesis surgeries in the last 5 years per year (mean ±SD & ranges)	40.76 ± 52.64 (0-250)	39.54 ± 33.58 (1-150)	0.3587	48.03 ± 52.80 (0-250)	45.38 ± 36.11 (0-150)	0.7561
Number of scientific articles read per month (mean ±SD & ranges)	10.73 ± 13.14 (1-60)	5.58 ± 4.13 (0-16)	0.1078	8.84 ±8.55 (1-30)	9.00 ± 6.37 (2-30)	0.2468

This table describes training background and experience of our neurosurgeons and orthopedic spine surgeons within PG and RG. Experience is measured with years of board certification. Training background is calculated with exact numbers of performed surgeries in career, over the last 5 years, certain spinal pathologies, and the amount of scientific articles read per month. For each parameter means, standard deviations (SDs), and ranges are calculated. P-values to compare neurosurgeons and orthopedic spine surgeons within PG and RG are provided. The statistical evaluation shows that both groups are comparable. Significant differences are displayed in bold.

Summarizing these results, our subgroups of neurosurgeons and orthopedic spine surgeons are numerically balanced and highly comparable regarding participants' training background and experience. This is the same across the PG and the RG.

3.3 Results of the three patient cases

For each of the following three patient cases, results are primarily compared between the subgroups of neurosurgeons and orthopedic spine surgeons. This is to confirm or refute our first hypothesis that medical specialty affiliation does not affect the indication in spinal surgery. To confirm or refute our second hypothesis that personal emotional involvement does not impact the treatment indication in spinal surgery we compare the results of the PG to the RG. In order to confirm or refuse the third hypothesis that the experience of board-certified surgeons does not influence the indication in spinal surgery, we compare the results of physicians with less than 10 years to the ones with greater equal 10 years of board certification within the respective specialty group.

3.3.1 Results of lumbar disc herniation

3.3.1.1 Decision-making of neurosurgeons versus orthopedic spine surgeons

According to the current literature for lumbar DH there are no clear treatment recommendations. Patients can benefit from both surgery and conservative treatment. Thus we compare indication for surgery and conservative treatment between our medical subgroups.

Regarding treatment indication for lumbar DH, decision-making between neurosurgeons and orthopedic spine surgeons differs significantly. *Figure 10* shows participants' answers in percentages. The p-value of p=0.0011 (OR=4.1, 95% CI=[1.7 – 9.7], *Figure 10, Table 8*) indicates that there is a significant difference when recommending surgery between neurosurgeons and orthopedic spine surgeons. Absolute numbers show that neurosurgeons significantly more often recommend surgery than orthopedic spine surgeons.

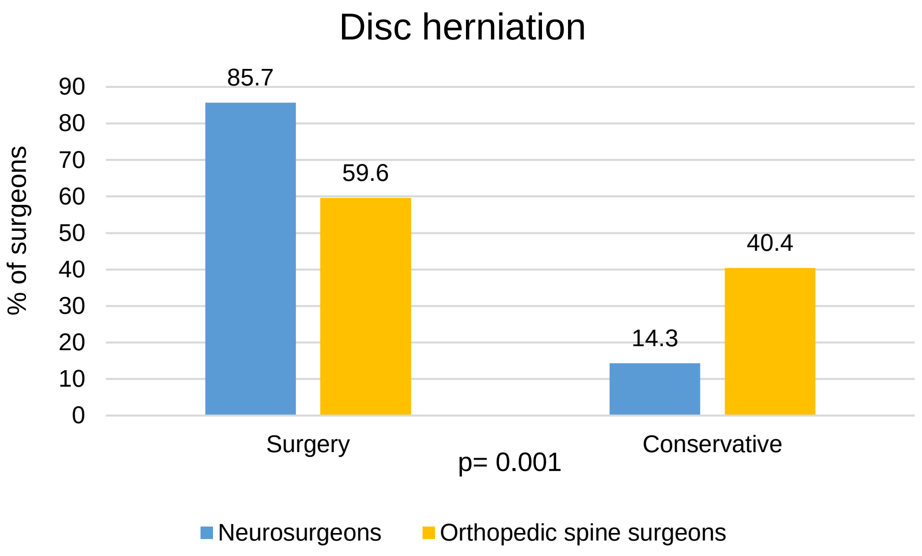


Figure 10: Treatment suggestion for lumbar disc herniation (DH)

This figure depicts the results regarding treatment indication for lumbar DH between neurosurgeons and orthopedic spine surgeons. Neurosurgeons (shown in blue) recommend more often surgery than orthopedic spine surgeons (shown in yellow). The stated p-value indicates the significant difference between the two specialties. Results of this bar graph are listed as percentages.

As *Table 8* shows, 60 out of 70 neurosurgeons (85.7%) recommend surgery for this patient case. Especially neurosurgeons of the RG recommend surgery far more often than orthopedic spine surgeons within this group (83.8% neurosurgeons vs. 50.0% orthopedic spine surgeons, p=0.0040, *Table 8*). Only 14.3% consider conservative treatment. When focusing on the years of board certification of neurosurgeons no significant differences could be observed: 80.5% of physicians with less than 10 years and 91.2% of physicians with greater equal 10 years favor surgery. A p-value of p=0.2043, does not indicate significant differences.

Regarding the group of orthopedic spine surgeons, *Table 8* shows that 59.6% recommend primarily surgery and 40.4% conservative treatment. 55.6% of orthopedic spine surgeons with less than 10 years of board certification and 60.0% with greater or equal to 10 years of board certification choose initial surgery. Consequently no significant differences in decision-making due to years of board certification are observed. The p-value is p=0.7458.

Table 8 summarizes the results regarding the basis of decision-making, certainty in decision-making and former consultation of relatives. It shows that from all participants merely 24.6% indicate that their decision-making is based on scientific literature. The majority of 75.4% refers to their experience and to their gut feeling as basis for decision-making. Of the participants who base their decision on scientific evidence, 83.3% name the exact scientific work by name. Of these, 46.6% state that they obtained their knowledge from the SPORT trials and Sciatica trial, another 16.6% state different reviews as their source, but which again cited the SPORT trials and Sciatica trial in their work.

Table 8: Results of decision-making between neurosurgeons and orthopedic spine surgeons for patients with lumbar disc herniation (DH)

		Neurosurgeons	Orthopedic spine surgeons	**OR** (95% CI)	p-value
Treatment recommendation overall (%)	Surgery	85.7	59.6	4.1 (1.7-9.7)	**0.0011**
	Conservative	14.3	40.4		
Treatment recommendation only PG (%)	Surgery	87.9	69.2	3.2 (0.8-12.3)	0.0773
	Conservative	12.1	30.8		
Treatment recommendation only RG (%)	Surgery	83.8	50.0	5.2 (1.6-16.6)	**0.0040**
	Conservative	16.2	50.0		
Basis of decision-making (%)	Gut feeling/ experience	77.1	73.1	1.2 (0.5-2.8)	0.6060
	Scientific evidence	22.9	26.9		
Certainty in decision-making (means in % ± SD & ranges)		90.6 ± 9.3 (70-100)	85.4 ± 12.3 (50-100)	-	**0.0208**
Former consultation of relatives (%)	Yes	72.9	84.6	0.5 (0.2-1.2)	0.1218
	No	27.3	15.4		

This table compares treatment recommendations between neurosurgeons and orthopedic spine surgeons for the lumbar DH case. Results regarding overall treatment recommendation, only in the patient group (PG), only in the relative group (RG), basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

Both medical specialties are remarkably confident in their decision-making: neurosurgeons with a mean of 90.6% of certainty in decision-making and orthopedic spine surgeons with a mean of 85.4%. It appears that neurosurgeons are significantly more certain than orthopedic spine surgeons in our survey with a p-value of p=0.0208.

77.9% of our participating physicians state that they have previously advised own relatives who suffered from lumbar DH.

Table 9: Further details of treatment recommendation between neurosurgeons and orthopedic spine surgeons for lumbar disc herniation

<table>
<tr><th colspan="3"></th><th>Neurosurgeons</th><th>Orthopedic spine surgeons</th><th>Totals</th></tr>
<tr><td rowspan="5">Surgical treatment</td><td rowspan="4">Decompression</td><td>Interlaminar fenestration</td><td>57</td><td>18</td><td>75</td></tr>
<tr><td>Laminectomy</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Hemilaminectomy</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Endoscopic</td><td>3</td><td>10</td><td>13</td></tr>
<tr><td colspan="2">Decompression & stabilization</td><td>0</td><td>2</td><td>2</td></tr>
<tr><td colspan="2" rowspan="3">Conservative treatment</td><td>Physiotherapy</td><td>4</td><td>5</td><td>9</td></tr>
<tr><td>Analgesics</td><td>1</td><td>1</td><td>2</td></tr>
<tr><td>Infiltrations</td><td>5</td><td>15</td><td>20</td></tr>
<tr><td colspan="2">Totals</td><td></td><td>70</td><td>52</td><td>122</td></tr>
</table>

This table depicts the specific results regarding surgical and conservative treatment between neurosurgeons and orthopedic spine surgeons. Surgical treatment implies decompression and decompression plus stabilization. Conservative treatment consists of physiotherapy, analgesics, and infiltrations.

Table 9 shows which surgery or conservative treatment the participants choose. It shows that 89 of the 91 physicians who recommend initial surgery, favor decompression which results from interlaminar fenestration, laminectomy, hemi-laminectomy or endoscopic interventions. Only 2 orthopedic spine surgeons favor decompression and stabilization as primer therapy for patients with lumbar DH.

From the 31 physicians who recommend conservative treatment primarily, 20 (64.5%) select infiltrations as best conservative option, 9 (29.0%) select physiotherapy, and 2 (6.5%) choose pain therapy with analgesics. Of those 31 physicians who recommend initial conservative treatment, 22 (71.0%) would suggest surgery for patients who still suffer from persisting pain after conservative treatment. For patients with exacerbation of pain after conservative treatment, 8 physicians (25.8%) would recommend surgery. Only one physician would never consider surgery for patients with lumbar DH.

3.3.1.2 Decision-making of patient group versus relative group

Our results show no statistically significant differences in decision-making between our PG and RG for the first patient case. This is indicated by the p-value of p=0.2131 (OR=1.7, 95% CI=[0.8 – 3.8]) in *Figure 11* and *Table 10*. *Figure 11* also shows participants' answers in percentages.

As shown in *Table 10*, 47 out of 59 participants (79.7%) in the PG recommend surgery for this patient case. Only 20.3% consider conservative treatment. In addition, no significant difference is observed when comparing separately neurosurgeons' and orthopedic spine surgeons' decision-making between PG and RG (p=0.6250 neurosurgeons vs. p=0.1576 orthopedic spine surgeons, *Table 10*).

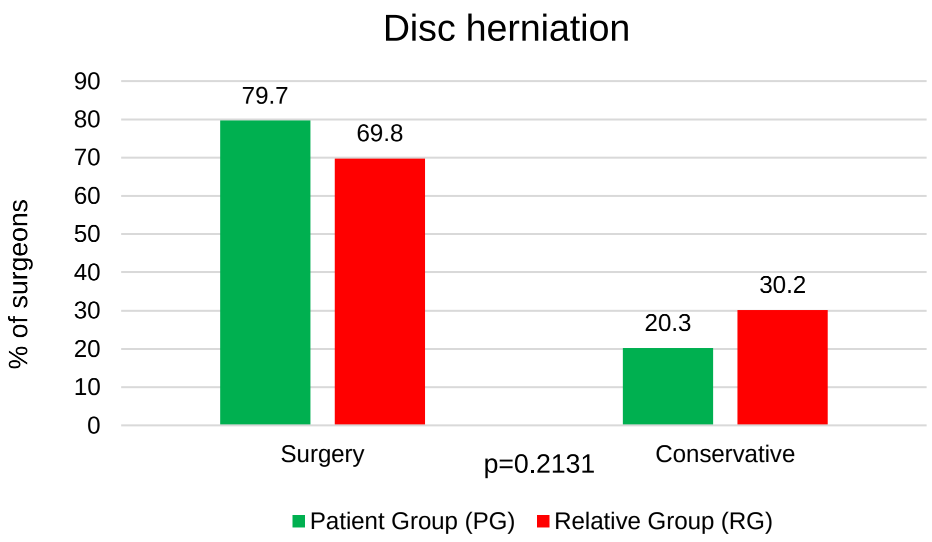


Figure 11: Treatment suggestion for lumbar disc herniation (DH) between PG and RG

This figure depicts the results regarding treatment indication for lumbar DH between PG and RG. In the PG (shown in green) surgery was recommended more often than in the RG (shown in red). The stated p-value indicates no significant differences between the two subgroups. Results of this bar graph are listed as percentages.

Regarding the RG, *Table 10* shows that 69.8% of participants recommend primarily surgery and 30.2% conservative treatment. Compared to the PG, there is a slight trend towards a more conservative approach in the RG.

Table 10 summarizes the results regarding basis of decision-making, certainty in decision-making and former consultation of relatives. It shows that more than 74% of each group base decision-making on gut feeling and experience than on scientific literature. Certainty for decision-making in both groups is higher than 88%.

Physicians within the PG are far more likely to have formerly consulted relatives than in the RG (p=0.0082, OR=3.5, 95% CI=[1.3-8.6]).

Table 10: Results of decision-making between patient group (PG) and relative group (RG) for patients with lumbar disc herniation (DH)

		PG	RG	OR (95% CI)	p-value
Treatment recommendation overall (%)	Surgery	79.7	69.8	1.7 (0.8-3.8)	0.2131
	Conservative	20.3	30.2		
Treatment recommendation only neurosurgeons (%)	Surgery	87.9	83.8	1.4 (0.4 – 5.5)	0.6250
	Conservative	12.1	16.2		
Treatment recommendation only orthopedic spine surgeons (%)	Surgery	69.2	50.0%	2.3 (0.7-7.0)	0.1576
	Conservative	30.8	50.0%		
Basis of decision-making (%)	Gut feeling/ experience	76.3	74.6	1.1 (0.5-2.5)	0.8307
	Scientific evidence	23.7	25.4		
Certainty in decision-making (means in % ± SD & ranges)		88.6 ± 10.1 (70-100)	88.1 ± 11.2 (50-100)	-	0.9210
Former consultation of relatives (%)	Yes	88.1	68.3	3.5 (1.3-8.6)	**0.0082**
	No	11.9	31.7		

This table shows treatment recommendations between the PG and RG for the lumbar DH case. Results regarding overall treatment recommendation, only neurosurgeons, only orthopedic spine surgeons, basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

3.3.2 Results of lumbar spinal stenosis

3.3.2.1 Decision-making of neurosurgeons versus orthopedic spine surgeons

Current scientific literature for this patient case recommends initial decompression surgery. Indicating ILF, laminectomy or hemilaminectomy is considered as level of evidence treatment in our survey. Overtreatment contains stabilization, undertreatment is considered when recommending conservative treatment. Thus we compare the level of evidence treatment, overtreatment and undertreatment between medical specialties.

Regarding treatment indication for lumbar SS, decision-making between neurosurgeons and orthopedic spine surgeons differs significantly. *Figure 12* shows participants' answers in percentages. The p-value of p=0.0004 (OR=3.9, 95% CI=[1.8 – 8.2], *Figure 12, Table 11*) indicates that there are significant differences regarding recommendation of level of evidence treatment between neurosurgeons and orthopedic spine surgeons. Neurosurgeons significantly more often recommend level of evidence treatment than orthopedic spine surgeons.

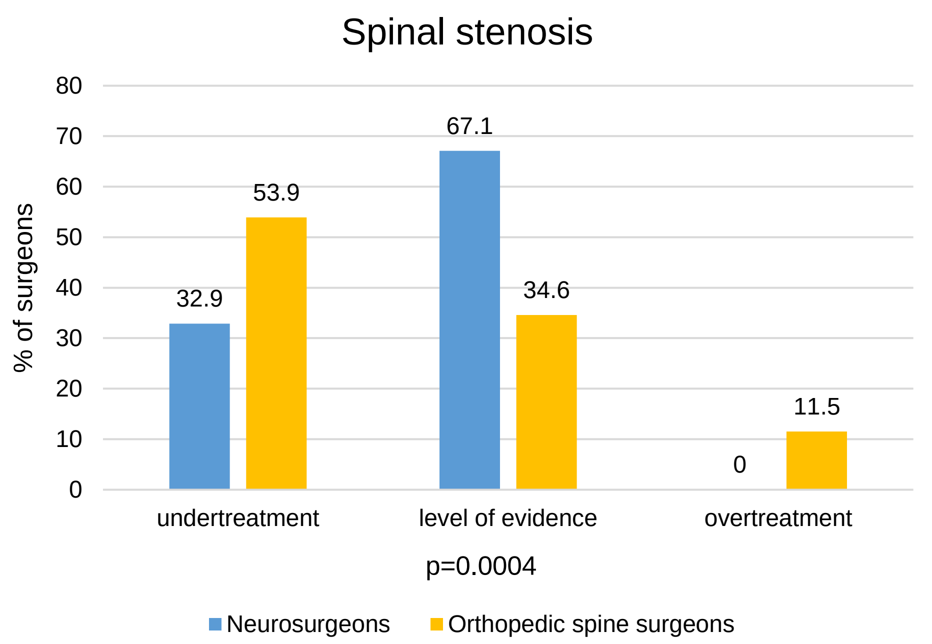


Figure 12: Treatment suggestion for lumbar spinal stenosis (SS)

This figure depicts the results regarding treatment indication for lumbar SS between neurosurgeons and orthopedic spine surgeons. Neurosurgeons (shown in blue) recommend more often level of evidence treatment than orthopedic spine surgeons (shown in yellow). Orthopedic spine surgeons choose far more often over- and undertreatment. The stated p-value indicates the significant difference between the two specialties. Results of this bar graph are listed as percentages.

As *Table 11* shows, 47 out of 70 neurosurgeons (67.1%) recommend level of evidence treatment for this patient case. Especially neurosurgeons of the RG recommend the "state of the art" far more often than orthopedic spine surgeons within this group (62.2% neurosurgeons vs. 23.1% orthopedic spine surgeons, p=0.0022, *Table 11*). 32.9% of neurosurgeons consider conservative treatment and none selects overtreatment.

Table 11: Results of decision-making between neurosurgeons and orthopedic spine surgeons for patients with lumbar spinal stenosis (SS)

		Neuro-surgeons	**Orthopedic spine surgeons**	**OR** (95% CI)	**p-value**
Treatment recommendation overall (%)	Level of evidence treatment	67.1	34.6	3.9 (1.8-8.2)	**0.0004**
	Overtreatment	0	11.5		
	Undertreatment	32.9	53.9		
Treatment recommendation only PG (%)	Level of evidence treatment	72.7	46.2	3.1 (1.0-9.2)	0.0377
	Overtreatment	0	3.8		
	Undertreatment	27.3	50.0		
Treatment recommendation only RG (%)	Level of evidence treatment	62.2	23.1	5.5 (1.8-16.9)	**0.0022**
	Overtreatment	0	19.2		
	Undertreatment	37.8	57.7		
Basis of decision-making (%)	Gut feeling/ experience	77.1	78.8	0.9 (0.4-2.2)	0.8227
	Scientific evidence	22.9	21.2		
Certainty in decision-making (means in % ± SD & ranges)		86.0 ±11.8 (60-100)	85.6 ± 12.0 (50-100)	-	0.8590
Former consultation of relatives (%)	Yes	77.1	65.4	1.8 (0.8-4.0)	0.1520
	No	22.9	34.6		

This table compares treatment recommendations between neurosurgeons and orthopedic spine surgeons for the lumbar SS case. Results regarding overall treatment recommendation, only in the patient group (PG), only in the relative group (RG), basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

When focusing on the years of board certification of neurosurgeons no significant differences could be observed: 72.2% of physicians with less than 10 years and 61.8% of physicians with greater equal 10 years favor level of evidence surgery. A p-value of p=0.3519 does not indicate significant differences.

Regarding the group of orthopedic spine surgeons, *Table 11* shows that 34.6% recommend level of evidence treatment, 11.5% recommend overtreatment, and 53.9% conservative treatment. 40.7% of orthopedic spine surgeons with less than 10 years of board certification and 28.0% with greater equal 10 years of board certification choose level of evidence surgery. Consequently no significant differences in decision-making due to years of board certification are observed, noting a p-value of p=0.3346.

Table 11 summarizes the results regarding basis of decision-making, certainty in decision-making and former consultation of relatives. It shows that from all participants merely 22.1% indicate that their decision-making is based on scientific literature. The majority of 78.0% refers to their experience and to their gut feeling as basis for decision-making.

Of the participants who base their decision on scientific evidence, 81.5% name the exact scientific work by name. Of these, 36.4% state that they obtained their knowledge from the SPORT trials and Sciatica trial, another 18.2% state the German clinical practice guidelines for specific LBP which again cited the SPORT trials and Sciatica trial in their work.

Both medical specialties show a remarkable certainty in their decision-making, neurosurgeons with a mean of 86.0% and orthopedic spine surgeons with 85.6% of certainty. Since the p-value of p=0.8590 is greater than our significance level, the results are not considered as significant.

A mean of 71.3% of our participating physicians state that they have already advised own relatives who suffered from lumbar SS.

Table 12 shows which surgery or conservative treatment our participants choose. All 47 neurosurgeons who choose initial surgical therapy, recommend decompression like interlaminar fenestration and hemi-laminectomy. Thus 100% of neurosurgeons who consider initial surgical therapy, follow literature's evidence. Of the 24 orthopedic spine surgeons who consider initial surgery, 18 surgeons (75.0%) also follow literature by choosing ILF or hemilaminectomy. Remaining 6 surgeons (25.0%) indicate overtreatment. Three of them choose dynamic stabilization with decompression, the other three dynamic stabilization alone. From the 51 physicians who recommend conservative treatment primarily, 31 (60.8%) select infiltrations as best conservative option, 19 (37.3%) select physiotherapy, and 1 (2.00%) choose pain therapy with analgesics. Of those 51 physicians who recommend initial conservative treatment, 22 (43.1%) would suggest surgery for patients who still suffer from persisting pain after conservative treatment. For patients with exacerbation of pain after conservative treatment, 28 physicians (54.9%) would recommend surgery. Only one physician would never consider surgery for patients with lumbar SS.

In summary 53.3% of all attending doctors recommend level of evidence treatment, whereas 41.8% of all physicians recommend undertreatment and only 4.9% recommend overtreatment.

Table 12: Further details of treatment recommendation between neurosurgeons and orthopedic spine surgeons for lumbar spinal stenosis (SS)

<table>
<tr><th></th><th>Neuro-surgeons</th><th>Orthopedic spine surgeons</th><th></th><th>Neuro-surgeons</th><th>Orthopedic spine surgeons</th></tr>
<tr><td>ILF</td><td>38</td><td>16</td><td rowspan="5">Surgery</td><td rowspan="5">47</td><td rowspan="5">24</td></tr>
<tr><td>Laminectomy,</td><td>0</td><td>0</td></tr>
<tr><td>Hemilaminectomy,</td><td>9</td><td>2</td></tr>
<tr><td>Stabilization & decompression</td><td>0</td><td>3</td></tr>
<tr><td>Stabilization without decompression</td><td>0</td><td>3</td></tr>
<tr><td>Physiotherapy</td><td>10</td><td>9</td><td rowspan="3">Conservative</td><td rowspan="3">23</td><td rowspan="3">28</td></tr>
<tr><td>Analgesics</td><td>1</td><td>0</td></tr>
<tr><td>Infiltrations</td><td>12</td><td>19</td></tr>
<tr><td></td><td></td><td></td><td>p-value</td><td colspan="2">0.0201</td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td colspan="2">2.384</td></tr>
<tr><td></td><td></td><td></td><td>95% CI</td><td colspan="2">1.138 – 4.992</td></tr>
</table>

This table depicts the specific results regarding surgical and conservative treatment between neurosurgeons and orthopedic spine surgeons for the lumbar SS case. Surgical treatment implies interlaminar fenestration (ILF), laminectomy, hemilaminectomy, decompression with stabilization, and stabilization alone. Conservative treatment consists of physiotherapy, analgesics, and infiltrations. When comparing conservative to surgical treatment no significant differences are shown, this indicates the p-value. Additionally odds ratios (ORs) and 95% confidence intervals (CIs) are listed.

3.3.2.2 Decision-making of patient group versus relative group

Our results show no statistically significant differences in decision-making between our PG and RG for the lumbar SS case This is indicated by the p-value of p=0.0973 (OR=1.8, 95% CI=[0.9 – 3.7]) in *Figure 13* and *Table 13*. But there is a trend towards more over-and undertreatment in the RG compared to the PG. *Figure 13* shows participants' answers in percentages.

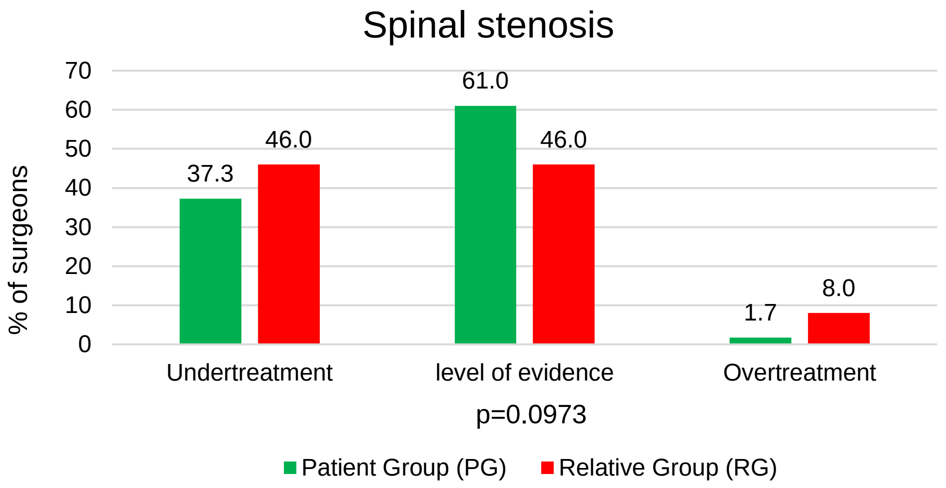


Figure 13: Treatment suggestion for lumbar spinal stenosis (SS) between PG and RG

This figure depicts the results regarding treatment indication for lumbar SS between the PG and RG. Participants of the PG (shown in green) recommend more often level of evidence treatment than participants of the RG (shown in red). Participants of the RG choose far often over- and undertreatment. The stated p-value indicates that there are no significant differences between the two subgroups. Results of this bar graph are listed as percentages.

As shown in *Table 13*, 36 out of 59 participants (61.0%) in the PG recommend level of evidence treatment for this patient case. 1.7% consider overtreatment and 37.3% conservative treatment. No significant difference is observed when comparing separately neurosurgeons' and orthopedic spine surgeons' decision-making between PG and RG (p=0.3475 neurosurgeons vs. p=0.0803 orthopedic spine surgeons, *Table 13*).

Regarding the RG, *Table 13* shows that 46.0% of participants recommend primarily level of evidence treatment, 8.0% recommend overtreatment, and 46.0% conservative treatment. Noticeable is a trend towards more conservative treatment of our participating orthopedic spine surgeons in the PG as well as in the RG.

Table 13 summarizes the results regarding basis of decision-making, certainty in decision-making, and former consultation of relatives. It shows that more than 77% of each group base decision-making on gut feeling and experience, than on scientific literature. Certainty for decision-making in both groups is higher than 85.0%.

Physicians within the PG name far more often former consultation of relatives than in the RG (p=0.0092, OR=3.0, 95% CI=[1.3-7.1]).

Table 13: Results of decision-making between patient group (PG) and relative group (RG) for patients with lumbar spinal stenosis (SS)

		PG	RG	OR (95% CI)	p-value
Treatment recommendation overall (%)	Level of evidence treatment	61.0	46.0	1.8 (0.9-3.7)	0.0973
	Overtreatment	1.7	8.0		
	Undertreatment	37.3	46.0		
Treatment recommendation only neurosurgeons (%)	Level of evidence treatment	72.7	62.2	1.6 (0.6-4.5)	0.3475
	Overtreatment	0	0		
	Undertreatment	27.3	37.8		
Treatment recommendation only orthopedic spine surgeons (%)	Level of evidence treatment	46.2	23.1	2.9 (0.9-9.4)	0.0803
	Overtreatment	3.8	19.2		
	Undertreatment	50.0	57.7		
Basis of decision-making (%)	Gut feeling/ experience	78.0	77.8	1.0 (0.4-2.5)	0.9800
	Scientific evidence	22.0	22.2		
Certainty in decision-making (means in % ± SD & ranges)		85.0 ± 11.6 (50-100)	87.0 ± 12.1 (50-100)	-	0.2924
Former consultation of relatives (%)	Yes	83.1	61.9	3.0 (1.3-7.1)	**0.0092**
	No	16.9	38.1		

This table shows treatment recommendation between the PG and RG for the lumbar SS case. Results regarding overall treatment recommendation, only neurosurgeons, only orthopedic spine surgeons, basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

3.3.3 Results of lumbar spondylolisthesis

3.3.3.1 Decision-making of neurosurgeons versus orthopedic spine surgeons

When we conducted the INDIANA survey, current scientific literature for patients with lumbar SL recommend initial decompression surgery plus fusion. Indicating dynamic stabilization and fusion is considered as level of evidence treatment in our survey. Undertreatment is considered when recommending conservative treatment or when performing only decompression surgery. Thus we compare level of evidence treatment and undertreatment between medical specialties.

Regarding treatment indication for lumbar SL, for the first time in our survey, decision-making between neurosurgeons and orthopedic spine surgeons does not differ significantly. *Figure 14* shows participants' answers in percentages. The p-value of p=0.7618 (OR=0.8, 95% CI=[0.2 – 3.5], *Figure 14, Table 14*) indicates that there is no significant difference between neurosurgeons and orthopedic spine surgeons.

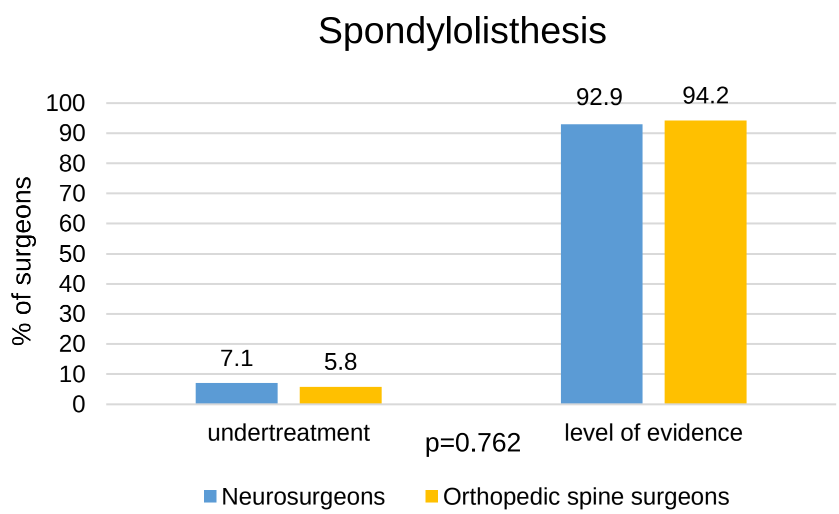


Figure 14: Treatment suggestion for lumbar spondylolisthesis (SL)

This figure depicts the results regarding treatment indication for lumbar SL between neurosurgeons and orthopedic spine surgeons. There are no significant differences between neurosurgeons (shown in blue) and orthopedic spine surgeons (shown in yellow). This shows the stated p-value. Results of this bar graph are listed as percentages.

As *Table 14* shows, 65 out of 70 neurosurgeons (92.9%) recommend level of evidence treatment for this patient case. All neurosurgeons choose initial surgery, only 7.1% recommend decompression surgery alone, which is considered as undertreatment for this patient case. None of neurosurgeons considers conservative treatment. When focusing on the years of board certification of neurosurgeons, no significant differences could be observed: 94.4% of physicians with less than 10 years, and 91.2% of physicians with greater equal 10 years favor level of evidence surgery. A p-value of p=0.5957, does not indicate significant differences.

Regarding the group of orthopedic spine surgeons, *Table 14* shows that 94.2% recommend primarily surgery and only 5.8% conservative treatment. 96.3% of orthopedic spine surgeons with less than 10 years of board certification, and 92.0% with greater equal 10 years of board certification choose level of evidence therapy. Consequently no significant differences in decision-making due to years of board certification are observed, indicated by a p-value of p=0.5668.

Table 14: Results of decision-making between neurosurgeons and orthopedic spine surgeons for patients with lumbar spondylolisthesis (SL)

		Neuro-surgeons	**Orthopedic spine surgeons**	**OR** (95% CI)	**p-value**
Treatment recommendation overall (%)	Level of evidence treatment	92.9	94.2	0.8 (0.2-3.5)	0.7618
	Undertreatment	7.1	5.8		
Treatment recommendation only PG (%)	Level of evidence treatment	90.9	96.2	0.4 (0.0-4.1)	0.4263
	Undertreatment	9.1	3.8		
Treatment recommendation only RG (%)	Level of evidence treatment	94.6	92.3	1.5 (0.2-11.1)	0.7140
	Undertreatment	5.4	7.7		
Basis of decision-making (%)	Gut feeling/ experience	78.6	76.9	1.1 (0.5-2.6)	0.8283
	Scientific evidence	21.4	23.1		
Certainty in decision-making (means in % ± SD & ranges)		87.0 ± 11.0 (60-100)	89.0 ± 10.2 (50-100)	-	0.2772
Former consultation of relatives (%)	Yes	60.0	40.4	2.2 (1.1-4.6)	**0.0320**
	No	40.0	59.6		

This table compares treatment recommendations between neurosurgeons and orthopedic spine surgeons for the lumbar SL case. Results regarding overall treatment recommendation, only in the patient group (PG), only in the relative group (RG), basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

Table 14 summarizes the results regarding basis of decision-making, certainty in decision-making and former consultation of relatives. It shows that from all participants merely 22.3% indicate that their decision-making is based on scientific literature. The majority of 77.8% refers to their experience and to their gut feeling as basis for decision-making.

Of the participants who base their decision on scientific evidence, 81.5% name the exact scientific work by name. Of these, 45.5% state that they obtained their knowledge from the SPORT trials and Sciatica trial, another 13.6% state different reviews as their source, but they again cited the SPORT trials and Sciatica trial in their work.
Both medical specialties show a remarkable certainty in their decision-making, neurosurgeons with a mean of 87.0% and orthopedic spine surgeons with 89.0% of certainty. Since the p-value of p=0.2772 is greater than our significance level, the results are not considered as significant.
A mean of 50.2% of our participating physicians mention that they have already advised own relatives who suffered from lumbar SL. Neurosurgeons provide former consultation of relatives significantly more often than orthopedic spine surgeons. This indicates the p-value of p=0.0320 (OR=2.2, 95% CI=[1.1-4.6], *Table 14*).

Table 15: Further details of treatment recommendation between neurosurgeons and orthopedic spine surgeons for lumbar spondylolisthesis (SL)

	Neuro-surgeons	**Orthopedic spine surgeons**		**Neuro-surgeons**	**Orthopedic spine surgeons**
Dynamic stabilization	7	2	**Surgery**	70	49
Fusion	58	47			
Decompression	5	0			
Physiotherapy	0	0	**Conservative**	0	3
Analgesics	0	0			
Infiltrations	0	3			
p-value	0,7618		**p-value**	**0.0419**	
OR	0,7959		**OR**	9.970	
95% CI	0,1814 - 3,493		**95% CI**	0.5033 – 197.5	

This table depicts the specific results regarding surgical and conservative treatment between neurosurgeons and orthopedic spine surgeons for the lumbar SL case. Surgical treatment implies dynamic stabilization, fusion and decompression. Conservative treatment consists of physiotherapy, analgesics and infiltrations. When comparing conservative to surgical treatment significant differences were shown, this indicates the p-value. Additionally odds ratios (ORs) and 95% confidence intervals (CIs) are listed.

Table 15 shows which surgery or conservative treatment the participants choose. It shows that 114 of the 119 physicians who recommend initial surgery, favor decompression surgery plus fusion, and thus follow the level of evidence treatment. The remaining 4 participants, in this

case neurosurgeons, favor decompression surgery alone. This is considered as undertreatment for patients with lumbar SL.
All orthopedic spine surgeons who consider initial surgical therapy, follow literature's evidence by choosing decompression plus fusion and dynamic stabilization.
From the three physicians who recommend conservative treatment primarily, all are orthopedic spine surgeons, and all select infiltrations as best conservative option. Of those three physicians, two would indicate surgery for patients with exacerbation of pain and one would suggest surgery for patients who still suffer from persisting pain after conservative treatment.
In summary, 93.4% of all attending doctors recommend level of evidence treatment, whereas only 6.6% of all physicians recommend undertreatment.

3.3.3.2 Decision-making of patient group versus relative group

Our results show no statistically significant differences in decision-making between our PG and RG for the lumbar SL case. This is indicated by the p-value of p=0.9235 (OR=0.9, 95% CI=[0.3 – 3.3]) in *Figure 15* and *Table 16*. *Figure 15* also shows participants' answers in percentages.

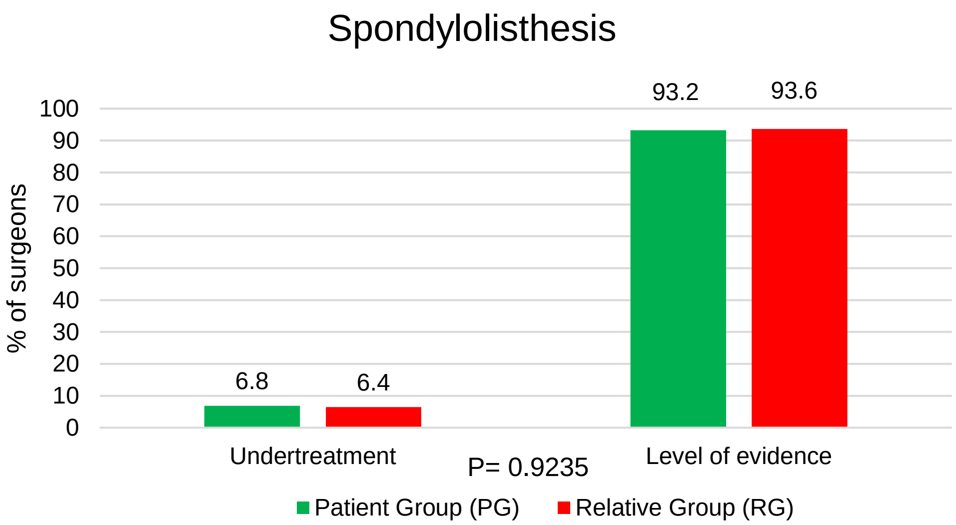


Figure 15: Treatment suggestion for lumbar spondylolisthesis (SL) between PG and RG

This figure depicts the results regarding treatment indication for lumbar SL between the PG and RG. Participants of the PG (shown in green) as well as participants of the RG (shown in red) recommend mostly level of evidence treatment. Only few participants of both subgroups choose undertreatment. The stated p-value indicates that there are no significant differences between the two subgroups. Results of this bar graph are listed as percentages.

As shown in *Table 16*, 55 out of 59 participants (93.2%) in the PG recommend level of evidence treatment for this patient case. Only 6.8% consider conservative treatment or decompression surgery alone. No significant difference as well is observed when comparing separately neurosurgeons' and orthopedic spine surgeons' decision-making between PG and RG (p=0.5500 neurosurgeons vs. p=0.5520 orthopedic spine surgeons, *Table 16*).

Table 16: Results of decision-making between patient group (PG) and relative group (RG) for patients with lumbar spondylolisthesis (SL)

		PG	RG	**OR** (95% CI)	**p-value**
Treatment recommendation overall (%)	Level of evidence treatment	93.2	93.6	0.9 (0.3-3.3)	0.9235
	Undertreatment	6.8	6.4		
Treatment recommendation only neurosurgeons (%)	Level of evidence treatment	90.9	94.6	0.6 (0.1-3.7)	0.5500
	Undertreatment	9.1	5.4		
Treatment recommendation only orthopedic spine surgeons (%)	Level of evidence treatment	96.2	92.3	2.1 (0.2-24.5)	0.5520
	Undertreatment	3.8	7.7		
Basis of decision-making (%)	Gut feeling/ experience	78.0	77.8	1.0 (0.4-2.4)	0.9800
	Scientific evidence	22.0	22.2		
Certainty in decision-making (means in % ± SD & ranges)		88.0 ± 10.0 (70-100)	88.0± 11.2 (50-100)	-	0.9472
Former consultation of relatives (%)	Yes	69.5	34.9	4.2 (1.9-8.6)	**0.0001**
	No	30.5	65.1		

This table shows treatment recommendation between the PG and RG for the lumbar SL case. Results regarding overall treatment recommendation, only neurosurgeons, only orthopedic spine surgeons, basis of decision-making, certainty, and former consultation of relatives are listed as percentages. Additionally also means, standard deviations (SDs), ranges, odds ratios (ORs) with 95% confidence intervals (CIs), and p-values are listed. Significant results are displayed in bold.

Regarding the RG, *Table 16* shows that 93.6% of participants recommend primarily level of evidence treatment, 6.4% recommend conservative treatment or decompression surgery alone.

Table 16 summarizes the results regarding basis of decision-making, certainty in decision-making and former consultation of relatives. It shows that more than 77% of each group base decision-making on gut feeling and experience, than on scientific literature. Certainty for decision-making in both groups is around 88.0%.

Physicians within the PG name far more often former consultation of relatives than in the RG (p=0.0001, OR=4.2, 95% CI=[1.9-8.6]).

3.3.4 Results of the regression-analyses

3.3.4.1 Confounding variables in lumbar disc herniation

With our first regression analysis the association between decision-making and training background and experience is investigated in order to reveal possible predictive variables for decision-making.

Table 17: Association of decision-making and training background & experience in patients with lumbar disc herniation (DH)

		OR (95% CI) (surgery vs. conservative)	**p-value**
Own relative counseled: yes vs. no		0.3 (0.1 – 1.1)	0.064
Professional experience	≤5 years vs. 6 – 20 years	0.3 (0.1 – 0.7)	**0.006**
	>20 years vs. 6 – 20 years	0.3 (0.1 – 1.1)	0.074
Number of spinal surgeries in career: >1,200 vs. ≤1,200		1.9 (0.8 – 4.2)	0.148
Number of spinal surgeries within the last 5 years (per year): >250 vs. ≤250		0.4 (0.2 – 1.2)	0.099
Number of scientific publications read per month: >15 vs. ≤15		1. 6 (0.4 – 5.9)	0.514

This table demonstrates the results of our regression analysis regarding potential predictive variables for decision-making in lumbar DH. Own relative counseled, professional experience, number of performed surgeries in career and within the last 5 years, as well as numbers of scientific articles read per month are listed as potential variables. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding p-values. Statistically significant p-values are considered for p<0.05 and are displayed in bold.

As *Table 17* shows, physicians with less than 5 years of experience choose far more often conservative treatment than physicians with more years of experience (p=0.0060). Therefore professional experience, reflected by the numbers of years as board-certified consultant, is assumed as a significant predictor variable regarding the decision-making process. We do not find other predictive variables for the patient case with lumbar DH.

The second regression analysis is used to detect confounding of medical specialty and personal emotional involvement by training background and experience. Confounding of decision-making by professional experience, which is considered as potential predictive variable, could be excluded *(Table 18)*. As *Table 18* shows, former consultation of own relatives instead is detected as potential confounder regarding decision-making and personal emotional involvement. The p-value of p=0.011 indicates this. Also in our model adjusted for former consultation of own relatives, the odds for recommendation of initial surgery in the PG is 0.5 times lower than in the RG (95% CI=[0.19-1.10], p=0.080).

Table 18: Table: Results of confounder analyses regarding surgeons' medical specialty and personal emotional involvement of the surgeon

		Surgeons' medical specialty (neurosurgeon vs. orthopedic spine surgeon)		**Personal emotional involvement** (RG vs. PG)	
		OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**
Own relative counseled: yes vs. no		0.5 (0.2 – 1.2)	0.126	**0.3 (0.1 – 0.8)**	**0.011**
Professional experience	≤5 years vs. 6 – 20 years	0.9 (0.4 – 2.0)	0.865	1.4 (0.6 – 3.0)	0.403
	>20 years vs. 6 – 20 years	1.1 (0.3 – 4.2)	0.892	1.6 (0.4 – 6.3)	0.476
Number of spinal surgeries in career: >,1200 vs. ≤1,200		1.3 (0.6 – 2.7)	0.464	1.4 (0.7 – 2.8)	0.366
Number of spinal surgeries within the last 5 years (per year): >250 vs. ≤250		0.5 (0.2 – 1.3)	0.139	1.6 (0.6 – 4.0)	0.328
Number of scientific publications read per month: >15 vs. ≤15		**3.7** (1.0 – 13.8)	**0.049**	1.7 (0.6 – 4.9)	0.355

This table shows the results of the confounder analyses which investigated potential confounding of our results regarding decision-making and specialty, and decision-making and personal emotional involvement by training background and experience variables. As training background and experience variables own relative counseled, years of professional experience, number of spinal surgeries in career and within last 5 years, as well as numbers of scientific publications read per month are considered. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs) and with corresponding p-values. Statistically significant p-values are considered as p<0.1 and displayed in bold. Relative group (RG), patient group (PG).

The number of scientific publications read per month is shown to be a potential confounder regarding decision-making and surgeons' medical specialty. This indicates also the p-value of p=0.049 in *Table 18*. However, very similar, insignificant results could be shown in the confounder-adjusted model (OR = 0.9, 95% CI = [0.2-4.4], p = 0.910).

3.3.4.2 Confounding variables in lumbar spinal stenosis

In the second patient case, according to our results shown in *Table 19*, no potential predictor variables influencing decision-making are identified.

Table 19: Association of decision-making and training background & experience in lumbar spinal stenosis (SS)

		OR (95% CI) (level of evidence vs. overtreatment)	**p-value**	**OR (95% CI)** (level of evidence. vs. undertreatment)	**p-value**
Own relative counseled: yes vs. no		0.3 (0.1 – 1.6)	0.165	0.7 (0.3 – 1.5)	0.317
Professional experience	≤5 years vs. 6 – 20 years	0.4 (0.0 – 3.8)	0.419	3.2 (0.3 – 38.1)	0.739
	>20 years vs. 6 – 20 years	0.9 (0.4 – 1.9)	0.363	2.6 (0.6 – 11.4)	0.198
Number of spinal surgeries in career: >1,200 vs. ≤1,200		1.0 (0.2 – 5.5)	0.971	1.1 (0.5 – 2.2)	0.851
Number of spinal surgeries within the last 5 years (per year): >250 vs. ≤250		0.0	0.846	1.2 (0.5 – 3.0)	0.677
Number of scientific publications read per month: >15 vs. ≤15		0.0	0.835	1.0 (0.3 – 2.9)	0.985

This table demonstrates the results of our regression analysis regarding potential predictive variables for decision-making in lumbar SS. Own relative counseled, professional experience, number of performed surgeries in career and within the last 5 years, as well as numbers of scientific articles read per month are listed as potential variables. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs), and corresponding p-values. Statistically significant p-values are considered for p<0.05.

3.3.4.3 Confounding variables in spondylolisthesis

Alike the second patient case, for the SL case none of our training background and experience variables is identified as predictor variable, as shown in *Table 20.*

Table 20: Association of decision-making and training background & experience in lumbar spondylolisthesis (SL)

		OR (95% CI) (level of evidence vs. undertreatment)	**p-value**
Own relative counseled:	yes vs. no	3.0 (0.6 – 15.5)	0.190
Professional experience	≤5 years vs. 6 – 20 years	0.6 (0.1 – 2.9)	0.485
Professional experience	>20 years vs. 6 – 20 years	-	0.994
Number of spinal surgeries in career:	>1,200 vs. ≤1,200	3.2 (0.6 – 16.6)	0.163
Number of spinal surgeries within the last 5 years (per year):	>250 vs. ≤250	1.5 (0.3 – 7.8)	0.647
Number of scientific publications read per month:	>15 vs. ≤15	4.7 (1.0 – 21.8)	0.050

This table demonstrates the results of our regression analysis regarding potential predictive variables for decision-making in lumbar SL. Own relative counseled, professional experience, number of performed surgeries in career and within the last 5 years, as well as numbers of scientific articles read per month are listed as potential variables. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs), and corresponding p-values. Statistically significant p-values are considered for $p<0.05$.

4. Discussion

4.1 Decision-making and surgeons' training background and experience

Due to careful selection process and stratification, the two groups of neurosurgeons and orthopedic spine surgeons are highly comparable regarding training background and experience. Although absolute number of participants is higher in the group of neurosurgeons, both groups are big enough to allow meaningful comparisons.

In terms of work experience, reflected by the years of board certification, both groups are balanced. On average neurosurgeons have 10.10 years and orthopedic spine surgeons have 9.69 years of specific working experience as a board-certified physician (*Table 5*). As our participants' experience in both groups is balanced and relatively high, we have an optimal basis for comparison.

A study shows that clinical experience plays an important role in the treatment indication of diseases for which there are many conservative and surgical treatment options and where scientific evidence is contradictory. In such cases, clinical uncertainty arises. For this reason, decisions with clinical uncertainty are increasingly based on the physician's own experience rather than on scientific evidence (Irwin, et al., 2005). But in our study for all three pathologies exists clear level I evidence, which in this case could be considered as a certain "basic truth". Therefore we would expect for our study, with comparably experienced participants and with clear level I evidence, that participant's own clinical experience does not have large influence on their decision making.

Nevertheless, for the lumbar DH patient case professional experience is identified as a potential predictive variable (p=0.0060, OR=0.3, 95% CI=[0.1-1.1], *Table 17*). Participants with less than 5 years of board certification choose significantly more often conservative treatment in comparison to their more experienced colleagues. But when comparing the indication of physicians with less than ten years of board certification to those with ten and more years of board certification the results are no longer significant. However, there is still a trend towards a more conservative approach among less experienced colleagues. It is quite obvious that this difference is due to the varying individual experiences of surgeons. With increasing experience and recognizing familiar clinical situations, the decision-making process gets faster and often becomes easier. Inexperienced surgeons tend to more analytical and deductive approaches with fewer risks, for example when recommending conservative treatment, because of their limited previous experience (Crebbin, Beasley, & Watters, 2013).

Regarding the patient cases of lumbar SS and lumbar SL, professional experience is not considered as a potential predictive variable (*Table 19 & 20*). More importantly in our regression analyses professional experience is not identified as potential confounder variable (*Table 20*). Nevertheless, we were able to observe a small trend that physicians with less than 10 years of board-certification are more likely to indicate the state of the art treatment than their colleagues with ten or more years of board certification.

High surgery volume (numbers of performed surgeries), seems to result in better patient outcome, less complications, and lower mortality rates (Birkmeyer, et al., 2003; Bederman, et al., 2009). For our survey, surgeons from both subgroups report high numbers of overall spine surgeries performed in the past, as shown in *Table 5* and *Table 6*. In total, orthopedic spine surgeons had performed a higher number of overall spine surgeries in the last 5 years, although neurosurgeons performed more surgeries regarding lumbar DH, SS, and SL (*Table 5*). A possible explanation for this could be that a large proportion of overall spine surgeries are traumatic spine surgeries, which are mostly performed by orthopedic spine surgeons. However, neurosurgeons perform significantly more often surgery for lumbar DH, as shown in *Table 5* (p=0.0021). It is possible that orthopedic spine surgeons during their residency acquire a broader and more intensive spectrum of conservative treatment measures, which can explain the trend towards more conservative treatment for patients suffering from lumbar DH.

In general, the surgery volume of our participants is comparable to surgeons' volume in other countries, although our participants' surgery volume is even higher, as we only included surgeons specialized on the spine (Bederman, et al., 2009; Farjoodi, Skolasky, & Riley, 2011; Dasenbrock, et al., 2012)

4.2 Decision-making and scientific literature

Medical literature expands exponentially. While in 1950, the doubling time of medical knowledge still took 50 years, it decreased to 7 years in the 80s, it was about only 3.5 years in 2010, and it is expected to take 73 days in 2020 (Densen, 2011). This results in increasing numbers of publications and articles which make it easy nowadays to access scientific literature. The problem faced by physicians is rather to keep up with the huge overload of information.

Saint et al. (2000) find American physicians spend on average 4.4 hours per week reading medical journal articles, whereby internists spend more time on reading articles than surgeons or general practitioners. Participants of our survey on average read 8.51 scientific articles per month. Neurosurgeons seem to read more scientific articles (9.73 articles per month, *Tables 5 & 6*) than orthopedic spine surgeons (7.29 articles per month, *Tables 5 & 6*), however the difference is not significant, but we observe a strong trend. A possible explanation for the difference could be that neurosurgeons are more often employed in university hospitals. Thus

they are better integrated in the academic environment and often have a broader selection of literature through their free institutional access.
There is a general lack in up-to-date data on the reading behavior of physicians or rather neurosurgeons and orthopedic spine surgeons. A small German study investigates the reading behavior of German general and visceral surgeons and their preferences regarding subscriptions to scientific journals (Ronellenfitsch, Klinger, Buhr, & Post, 2015). This work shows, that the majority of participants possess individual subscriptions of, mostly German, surgical journals. Only a small proportion does not pay for individual subscriptions. In addition, it shows that the institutional access to professional journals is not yet satisfactory, in particular at smaller hospitals and at the level of medical practices. It is possible that physicians without personal or institutional access often have to read open-access publications. These publications are more likely to bypass the peer review procedure and thus their content might be of lower quality, which could have a negative influence on physicians' decision-making.
Although our participants read an average of two articles per week, not even a quarter of our participants, from both medical specialties, base their decision-making on scientific evidence. Only 24.6% of participants choose scientific literature as the basis of their decision-making for lumbar DH (*Table 8).* For the case of lumbar SS, 22.1% of participants refer to literature as basis of their decision-making (*Table 11*), and for the lumbar SL case it is 22.3% (*Table 14*). Considering that for all three pathologies there is actually level I evidence, this is an alarmingly low number at the time of evidence-based medicine (EBM). Nowadays physicians should be able to make evidence-based decisions in order to provide best clinical practice to their patients and to follow a continuing professional development.
Of the participants who base their decision on scientific evidence, over 80% also name a concrete study. Of these, 42.8% directly mention the large studies such as the SPORT and the Sciatica trials, while another 15.9% refer to their knowledge from different reviews which also mention the large SPORT and Sciatica trials in their references. There is a slight trend for neurosurgeons to refer more to large studies such as the SPORT and Sciatica trials and for orthopedic spine surgeons to refer more to reviews and thus only indirectly to large studies.
Although we could not show statistically significant differences in the results of literature as a basis for decision-making between orthopedic spine surgeons and neurosurgeons (*Tables 8, 11 & 14*), the number of literature read per month is discovered as a potential confounding variable for the association of decision-making and medical specialty (*Table 18*). Since neurosurgeons are more frequently employed at university hospitals and, as aforementioned, may have a closer connection to scientific literature, it is important to underline at this point, that neurosurgeons were not preferably included in the study. Thus this confounding factor was avoided by our study design.

After filling out the survey, several participants criticized that they only had the possibility to report if their decision-making is based on gut feeling and experience or scientific evidence, but not a mixture of those two possibilities. This option is not given in our questionnaire. It is highly likely that in reality most surgeons' decision-making results from a combination of the consideration of scientific evidence and years of training and experience. Nevertheless, there is a clear level I evidence for all three pathologies. In addition, we explicitly only asked surgeons from spine centers or surgeons specializing in spine surgery. All the more reason to expect at the time of EBM that specialists base their decision on the available scientific evidence and not on their gut feeling and experience. These two components should not be the basis for a decision at the time of EBM, but an evidence-based decision can be confirmed and strengthened in the course of time by one's own experience and gut feeling.

As a policy implication, these results suggest that medical schools should consider focusing more on scientific literature and on how to read articles “correctly”. This would make it easier to link the information from literature with the daily practice and treatment recommendation and it could probably increase the percentage of literature being a basis for decision-making.

Particularly because we included only those specialized and experienced physicians in our survey, it is all the more astonishing that so many participants base their treatment indications on their experience rather than on concrete scientific evidence.

This study therefore shows that it is absolutely necessary to integrate scientific evidence already in the training and to enable a consistent and high-quality training in the field of spinal surgery. There is now the possibility of continuing education programs with a more specialized training in spine surgery through organizations such as the AO Spine or direct fellowships in larger hospitals (The AO Foundation, 2004).

Since a few years, for quality assurance in spine surgery, the German Spine Society offers the certification as a Spine Center. There are general requirements for this, such as treatment spectrum (degenerative, traumatic, neoplastic spinal diseases), diagnostic facilities (X-ray, CT, MRT), interdisciplinary therapeutic facilities (intensive care unit, vascular surgery, neurology), which must be fulfilled. In addition, regular complication meetings, as mortality and morbidity conferences, as well as regular advanced training events must be held to ensure quality assurance and active participation in research and teaching. For quality control purposes, the data is collected and evaluated in the spinal column register.

In addition to the certification as a Spine Center, the interested physician can be trained as a spine surgeon. These projects are the first to enable uniform and structured further training in the field of spine surgery in Germany (Deutsche Wirbelsäulengesellschaft, 2006). Our study shows that these measures to improve quality, training and education are absolutely necessary in the field of spinal surgery.

4.3 Decision-making and personal emotional involvement

The debate on personal emotional involvement of physicians and whether physicians should treat or counsel own relatives or not, has a long history in medicine. Most medical organizations recommend treating own family members only for minor conditions, in case of emergency, and when no other qualified professional is available. In all other cases physicians should not treat family members, because the possible emotional involvement is feared to result in a lack of objectivity and to negatively influence the quality of care (American Medical Association, 2016; General Medical Counsil, 2013; Krall, 2008). Although indicating surgery is no minor condition, we want to investigate with our survey if personal emotional involvement of the physician plays a role in decision-making. Therefore we assigned our participants into two groups: the patient group PG and the relative group RG.

As evident from results in *Table 4*, the assignment of participants to PG and RG is very balanced and there are no significant differences in training background and experience of our participants between PG and RG. Also the distribution of the participants who have already advised relatives on the three degenerative pathologies is balanced in both groups.

The participants from the RG had to select a relative of appropriate patient age in the run-up of each patient case and had to treat the subsequent patient case as if this relative was the patient. Although this procedure was specified and even though none of our subgroups knew about the existence of the other, we do not observe significant differences between decision-making of PG and RG. This is, as in the results shown above, the same for all three patient cases. Nevertheless our successful setup allows us to show a trend towards more conservative approach when indicating treatment for own relatives and this although we have a manageable group size.

For lumbar DH, our participating physicians choose slightly more often conservative treatment in our RG than in the PG, but not significantly (p=0.2131 OR=1.7, 95% CI=[0.8 – 3.8], *Table 10*). For this patient case, former consultation of own relatives is a potential confounder of decision-making and personal emotional involvement (*Table 20*). However, the model adjusted for former consultation of own relatives shows that initial surgery in the PG is 0.5 times lower than in the RG (p=0.080).

For the association of decision-making and personal emotional involvement we show no significant differences between PG and RG when referring to lumbar SS (p=0.0973, OR=1.8, 95% CI=[0.9 – 3.7], *Table 13*). But again we observe a trend towards more conservative treatment in the RG for both specialties (*Table 13, Figure 13)*. In contrast to lumbar DH, where there is no right or wrong for conservative treatment, conservative treatment for lumbar SS is considered as undertreatment according to the current scientific evidence. This trend to more conservative treatment in the RG is probably due to orthopedics' recommendation, since 76.9% of them within the RG choose over/undertreatment for this patient case (*Table 13*). It is possible that this trend is a hint for orthopedic spine surgeons being more affected by personal and emotional involvement than neurosurgeons. For lumbar SS, we find no confounding by training background and experience variables.

Also for lumbar SL we find no significant differences regarding decision-making and personal emotional involvement between PG and RG p=0.9235, OR=0.9, 95% CI=[0.3 – 3.3], *Table 16*). Although for lumbar SL, there is also a significant difference for former consultation of own relatives between the PG and RG (p=0.0001, OR=4.2, 95% CI=[1.9-8.6], *Table 16*), this has not led to more conservative treatment. Both groups recommend level of evidence treatment, irrespective of former consultation of own relatives.

Even though results are not significant, former consultation of own relatives seems to be associated with recommending conservative treatment more often, especially in the lumbar DH and lumbar SS case (DH: OR=0.3, p=0.064 surgery vs. conservative, *Table 17*; SS: OR=0.3, p=0.0317 level of evidence vs. undertreatment, *Table 19*).

Almost 70% of our participating doctors indicated former consultation of relatives in situations comparable to our patient cases. As many other studies show, relatives seeking medical advice is a reality for most doctors (La Puma, Stocking, La Voie, & Darling, 1991; Reagan, Reagan, & Sinclair, 1994). Results of La Puma show that 99% of 461 participants report requests from family members for medical advice, diagnosis or treatment. 83% have prescribed medications for family members, 72% perform medical examination on them, and even 9% perform surgery on own relatives. Although this study was conducted 25 years ago, we observe quite similar results through our survey. We also reach an average high percentage of 70.0% of neurosurgeons and 63.5% of orthopedic spine surgeons with former consultation of own relatives. Especially for the lumbar DH case, average percentages of former consultation of own relatives for neurosurgeons and orthopedic spine surgeons are 78.75% (*Table 8*). These numbers emphasize that being asked for medical advice by own relatives indeed is still very common for physicians, although there are no strict rules whether to treat own relatives or not, so far.

On these grounds La Puma & Priest provide some questions every physician should answer before treating family members (La Puma & Priest, 1992). Those questions can be seen as guidelines which should help physicians decide if treating own family members is adequate or not.

Overall, there is very little scientific evidence on the subject of personal emotional involvement and decision-making in medicine. But a personal emotional relationship cannot only be formed between a doctor and patient, it can also completely affect the doctor, for example if he is the patient himself. In this context there are some scientific papers which investigate whether physicians recommend a different treatment for themselves, than for their patients (Garcia-Retamero & Galesic, 2012; Mendel, et al., 2010; Ubel, Angott, & Zikmund-Fisher, 2011). These studies emphasize that personal involvement may has an influence over decision-making, at least when the physician is the patient himself.

Only a few studies investigate whether there are different treatment indications for relatives compared to the rest of the population. When it comes to decisions for family members, parents are more likely to take more conservative measures for their children than for themselves (Dore, Stone, & Buchanan, 2014). About the recommendation of surgeries, as it is the case in our study, doctors tend to be more cautious with themselves and their relatives than with the rest of the population (Domenighetti, Casabianca, Gutzwiller, & Martinoli, 1993). These findings are therefore in line with our observed trend that doctors tend to undertreat their relatives and to adopt a more conservative approach when it comes to recommending surgery to relatives.

In contrast, a German-Spanish study shows that physicians in general would recommend surgery less often to their patients than for themselves (Garcia-Retamero & Galesic, 2014). 93% of their participants report fear of legal consequences as reason for their decision not to recommend surgery. It is important to note that the participants in this study belong to different disciplines and therefore the fear of legal consequences has a different presence in everyday working life. A survey by the AMA shows that general surgery and obstetrics/gynecology, with almost 70% each, have the highest incidence of claims. The probability of being sued in other surgical specialties is also around 57%. Approximately 90% of surgeons aged 55 years and older have already been sued in their careers (Kane, 2010). It is therefore obvious that the different occurrence of legal consequences within the respective specialty can influence the treatment decision differently. However, since only surgeons are included in our survey, it can be assumed that the fear of legal consequences is equally present in both groups of participants and therefore had no influence on the treatment recommendation.

Since treating own family members is recommended only for minor conditions and clearly not for surgery it is not surprising that there is a lack of scientific trials regarding this topic. Nevertheless, our study shows that doctors are often consulted by relatives regarding surgical decisions. It would therefore be important to formulate clear recommendations in this respect as well and to deal more with this topic in the future. Moreover, it would be interesting to see if future studies also observe our trend towards more conservative approaches when indicating treatment for relatives. Perhaps it will be possible to establish an even more intense emotional connection in order to get clearer results.

4.4 Decision-making and medical specialty

Until now, only a few studies investigate decision-making between the medical specialties of neurosurgeons and orthopedic spine surgeons. They mostly focus on cervical spine injuries and thoracolumbar injuries and not on lumbar spinal pathologies as we do (Arnold, et al., 2009; Rampersaud, et al., 2006).

For our three patient cases regarding lumbar DH, lumbar SS, and lumbar SL, we have clear results with significant differences between the two medical specialties of neurosurgeons and orthopedic spine surgeons, illustrated in *Figures 10,12 & 14* and *Tables 8, 11 & 14*. Especially for the case of lumbar DH and lumbar SS, our results show clear differences between the specialties with a trend towards more conservative treatment among orthopedic spine surgeons. The trend towards more conservative approach of orthopedic spine surgeons could be due to the much higher value of conservative treatment methods during their residency. A general tendency of orthopedic spine surgeons towards more conservative treatment for patients suffering from spinal problems is also observed in another small survey from Ontario (Bederman, et al., 2010). They do not have the same including criteria and not exactly the same patient cases, but nevertheless they focus on spinal pathologies and when to recommend surgery for patients with LBP.

The following part describes and discusses our results between neurosurgeons and orthopedic spine surgeons for each of our patient cases.

4.4.1 Lumbar disc herniation

As explained in the introduction, current scientific literature regarding surgical or conservative treatment for patients with lumbar DH is still contradictory. Early studies as the Maine Lumbar spine study compare surgical versus conservative treatment for patients with lumbar DH. They show greater improvement in function and more satisfaction in the surgically treated group than patients treated conservatively. This holds for one, five, and ten years of follow up (Atlas, et al., 1996; Atlas S. , Keller, Chang, Deyo, & Singer, 2001; Atlas S. , Keller, Wu, Deyo, & Singer, 2005). Work and disability outcomes are similar in both groups.

The SPORT trial shows similar results. The surgery group reports more rapid and better improvements in pain and function than the conservative group over a 2-year period (Weinstein J. , et al., 2006). The same applies for follow-up studies after four years and eight years (Weinstein, et al., 2008; Lurie J. , et al., 2014). Also in this study the surgery group achieves greater improvements in all primary and secondary measures of the study as pain, function, and satisfaction.

On the other side the Dutch “Leiden- The Hague sciatica trials” show faster pain relief only for the first year in the surgery group (Peul, et al., 2007). Their long-term outcomes after two and five years show no significant differences between surgical or conservative treatment (Peul, van den Hoult, Brand, Thomeer, & Koes, 2008; Lequin, et al., 2013). Also Österman et al. observe the same after a two year follow up (Österman, Seitsalo, & Karppinen, 2006).

A Swiss survey recently explores if patients, who underwent surgery for painful degenerative spinal disorders, reach a satisfactory level of pain until one year after surgery (Fekete, et al., 2016). For lumbar DH, 52% of investigated patients report to be “somewhat satisfied” with their current pain level. Results after two years postoperatively are not published yet.

Although many studies investigate surgical techniques and approaches for lumbar DH, there is still no best technique for operating on a disc prolapse (Jacobs, et al., 2012; Thomé, Barth, Scharf, & Schmiedek, 2005; Ruetten, Komp, Merk, & Godolias, 2008). In accordance to the aforementioned large trials and since there is still no best technique, we decided to compare indication for surgery versus conservative treatment and not different types of surgeries in our INDIANA survey.

Based on the comparable outcome of surgical and conservative treatment for patients who suffer from lumbar DH, it is even more interesting that we gain such clear and distinct results for each medical specialty, as shown in *Table 8, Table 9,* and *Figure 10*. According to our results 85.7% of neurosurgeons recommend surgery for our patients with lumbar DH. For the same case only 59.6% of orthopedic spine surgeons recommend surgery. This difference is significant with a p-value of p=0.0011 (*Figure 10*, *Table 8*). Despite its importance, there are only a few published scientific works regarding practice patterns between neurosurgeons and orthopedic spine surgeons.

Similar to our results, a small Korean study shows differences between the two medical specialties regarding spinal disorders (Hussain, Nasir, Moed, & Murtaza, 2011). For their lumbar DH case, surgeons could only choose between two surgical therapies, sequestrectomy and aggressive discectomy. 50% of their questioned neurosurgeons would perform sequestrectomy for those patients. In contrast, all of the participating orthopedic spine surgeons would perform aggressive discectomy instead.

These results pose the question of where these different treatment indications origin from. Even though we only included board-certified neurosurgeons and orthopedic spine surgeons who have already been specialists for the spine, a possible explanation could be found in their different residency and training programs.

Dvorak et al. report that neurosurgical training programs for residents dedicate 37% to spinal surgical training (Dvorak, et al., 2006). During orthopedic residency only 16% of the time is dedicated on spinal training. According to their study, neurosurgery graduates feel more confident performing spinal surgery than orthopedic graduates. Therefore most of the orthopedic residents completed a year as a spine fellow, in order to make up the leeway. Although this study was performed in Canada, in German residency programs, spinal training is also more present in neurosurgical residency than in the orthopedic one. How present spinal training is, shows the lists of prescribed contents and periods of specialty training for neurosurgery and orthopedic surgery in Germany (Bundesärztekammer, 2011; Bundesärztekammer, 2011).

Besides the temporal component used on spinal training during residency, also the different importance of conservative treatment may cause differences in decision-making between neurosurgeons and orthopedic spine surgeons. As their residency program shows, orthopedic spine surgeons have to perform conservative treatment, also for the spine, far more often than residents from neurosurgery (Bundesärztekammer, 2011). Neurosurgical patients often show serious problems with urgent need of surgery, where conservative treatment is no possibility. Therefore it is possible that due to their extensive conservative training during residency, orthopedic spine surgeons even after specializing in spinal problems are more familiar with non-surgical treatment than neurosurgeons.

Apart from our survey there are some other studies reporting differences in decision-making between neurosurgeons and orthopedic spine surgeons. They also interpret their differences in decision-making between medical specialties as a result of different training background during residency (Bederman, et al., 2009; Irwin, et al., 2005; Drew, Bhandari, Orr, Reddy, & Dunlop, 2002).

An American study shows no significant differences between decision-making of neurosurgeons and orthopedic spine surgeons, regarding recurrent lumbar DH (Lubelski, et al., 2016). According to this study, a physician's geographical localization within the US and physicians working place (hospital or medical practice) seem to influence treatment recommendation. Although we only included first appeared lumbar DH and not recurrent lumbar DH in our study, results of Lubelski et al. are in contrast to ours. They do not find any differences in decision-making due to medical specialty. But in contrast to their study, Mroz et al. show that, with a probability of 69%, two randomly selected spine surgeons would disagree on the surgical treatment for patients suffering from recurrent lumbar DH. This disagreement is not due to medical specialty, fellowship training or geographical localization (Mroz, et al., 2014).

In our INDIANA survey, 31% of all participants would not perform initial surgery for patients with lumbar DH. They would consider it in a second step, for example, when patients still suffer from pain after conservative treatment. This shows that timing of surgery could influence physicians' treatment indication as well.

Many different studies investigate the perfect timing for surgery in cases of lumbar DH (Peul, Arts, Brand, & Koes, 2009; Rothoerl, Woertgen, & Brawanski, 2002). Some studies show that long duration of symptoms leads to poor outcome, but patients with severe sciatica benefit most from surgery (Kleinstueck, et al., 2011; Rihn, et al., 2011).

Summing up, a perfect time for surgery for patients who suffer from lumbar DH is between two and 12 months (Sabnis & Diwan, 2014; Folman, Shabat, Catz, & Gepstein, 2008; Fisher, et al., 2004).
Although treatment indication of the two specialties differs significantly in this case, both groups are astonishingly certain in their decision-making. The fact that neurosurgeons, with 90.6% compared to orthopedic spine surgeons with 85.4%, have a significant greater certainty in their decision-making, may be related with the circumstance that neurosurgeons also read scientific literature more often, which is considered as a reliable source (p=0.0208**,** *Table 8*).

4.4.2 Lumbar spinal stenosis

Different studies compare the outcome of conservative and surgical treatment for patients with lumbar SS. Hence, there is clear level I evidence in favor of surgical treatment for those patients. The SPORT trial shows significantly better outcome in patients who underwent surgery regarding pain, function, satisfaction, and self-rated progress than in patients treated conservatively within 2 years after treatment. Conservatively treated patients improve only moderately over 2 years (Weinstein J. , et al., 2008). Four-year results maintain greater improvement for pain and function in patients treated surgically (Weinstein J. , et al., 2010). This is also the same in their eight-year follow-up (Lurie J. , et al., 2016).
A Swiss survey recently explores if patients who underwent surgery for painful degenerative spinal disorders reach a satisfactory level of pain until one year after surgery (Fekete, et al., 2016). In cases of lumbar SS, 45% of patients report acceptable pain levels one year after surgery. These results underline the positive effect of surgery on pain levels for patients suffering from lumbar SS. Results after two years postoperatively are not published yet.
For patients with lumbar SS, most common surgical interventions nowadays are decompression surgery and decompression surgery plus fusion. In the US, physicians often recommend decompression surgery plus fusion (Debono, et al., 2018). Therefore fusion surgery, especially for cervical stenosis, comprises more than 90% of performed surgeries in the US. Other interventions, such as motion-preserving techniques have considerably decreased in popularity (Arrojas, Jackson, & Grabowski, 2017).
But other studies show that patients do not have significantly better outcomes after surgical fusion than with decompression surgery alone. Thus, nowadays decompression without fusion seems to be totally sufficient for patients with lumbar SS (Försth, et al., 2016; Hallett, Huntley, & Gibson, 2007). We consider decompression surgery plus fusion as overtreatment in our INDIANA survey.
When comparing decision-making between neurosurgeons and orthopedic spine surgeons in our lumbar SS case, our results show significant differences between the two medical specialties (p=0.0004, *Figure 12, Tables 11 & 12*). 67.1% of our neurosurgeons indicate

decompression surgery (ILF, laminectomy, hemilaminectomy), which is considered as state of the art and thus level of evidence treatment. Only 46.1% of orthopedic spine surgeons favor initial surgery. 34.6% of them choose level of evidence treatment as decompression surgery alone, whereas 11.5% indicate decompression surgery plus fusion, which is considered as overtreatment (*Table 11*). This is in line with the observations from Bederman's study, which find that neurosurgeons more often perform decompression surgery and orthopedic spine surgeons more often perform fusion surgery (Bederman, et al., 2009).

It is notable that our survey shows significantly different results between medical specialties, although there is quite clear level I evidence in favor of surgery.

So far, only two small studies investigate similar content referring to lumbar SS between neurosurgeons and orthopedic spine surgeons (Hussain, Nasir, Moed, & Murtaza, 2011; Irwin, et al., 2005).

The Asian study compares indication for lumbar SS between neurosurgeons and orthopedic spine surgeons. Their participants could choose between two surgical options, interlaminar decompression, and decompressive laminectomy. Unlike our survey, no recommendation of conservative treatment was possible. All orthopedic spine surgeons and 80% of neurosurgeons choose decompressive laminectomy. The remaining 20% of neurosurgeons favor interlaminar decompression (Hussain, Nasir, Moed, & Murtaza, 2011).

In contrast to Hussain et al., Irwin et al. show no significant differences between neurosurgeons and orthopedic spine surgeons regarding treatment indication for patients with lumbar SS (Irwin, et al., 2005). In contrast to our survey, this study excludes physicians choosing conservative treatment. In comparison to those studies, the higher number of participants and very balanced training background and experience within our survey could be a possible explanation of different results.

Nevertheless, Irwin's study shows significant differences regarding age of surgeons and their indication for fusion, instrumentation, and surgical approach. Our INDIANA survey does not investigate influence of surgeons' age to decision-making. Instead, we focus on the relation between years of board certification, which is a proxy for experience, and treatment decision. As mentioned in our results no significant differences regarding years of board certification could be observed when indicating treatment for patients with lumbar SS.

Similar results regarding physicians' experience, shows the study by Stienen et al. (2015). They investigate clinical outcome of patients who suffered from lumbar DH or lumbar SS operated on by resident physicians, to those operated on by board-certified neurosurgeons.

A recent published study investigates indication variability for lumbar spinal conditions, including lumbar SL, in four countries. Even if they do not compare medical specialties to each other, their interrater agreement of neurosurgeons, orthopedic spine surgeons and between countries is very slight (Debono, et al., 2018). This result again points to the lack of consensus regarding treatment indication for spinal conditions.

From the surgeons recommending conservative treatment as first line therapy, more than half are orthopedic spine surgeons. Different training during residency and the higher presence of conservative treatment in orthopedics could be a possible explanation for more non-surgical treatment within the group of orthopedic spine surgeons. Additionally when comparing our results to studies from the US or Asia, different health care systems could have a major influence over doctors' decision-making and their treatment recommendation.

4.4.3 Lumbar spondylolisthesis

In contrast to lumbar DH, literature provides very clear treatment recommendations for patients with lumbar SL. Different studies, as for example the SPORT trial, already investigate this content and compare the outcome of conservative and surgical treatment to each other. The SPORT trial for degenerative SL shows that patients treated with surgery have greater improvement in pain, function, and personal satisfaction than patients treated conservatively. This holds for two years and four years (Weinstein, et al., 2007; Weinstein, et al., 2009). According to a Swiss survey, in cases of lumbar SL, 53% of patients report acceptable pain levels one year after surgery. These results underline the positive effect of surgery on pain levels for patients suffering from lumbar SL. Results after two years postoperatively are not published yet (Fekete, et al., 2016).

Results of decision-making between neurosurgeons and orthopedic spine surgeons in our INDIANA survey show no significant differences when comparing neurosurgeons and orthopedic spine surgeons (p=0.7618, OR=0.8, 95% CI=[0.2-3.5], *Figure 14,Tables 14 & 15*). Much more important is that both medical specialties (92.9% of neurosurgeons and 94.2% of orthopedic spine surgeons) follow the state of the art by recommending decompression surgery plus fusion. At this point, it is important to consider that this was the current treatment recommendation during our collection of data and evaluation of results. Thus in our survey we assume decompression surgery plus fusion as level of evidence treatment.

Nowadays the question "whether to fuse or not to fuse" is still highly discussed and a topic of current research. It seems that decompression surgery has comparable outcomes than decompression surgery plus fusion (Alvin, et al., 2016; Ghogawala, et al., 2016; Försth, et al., 2016).

Alvin et al. find that patients who underwent fusion surgery have better quality of life improvements than with decompression surgery alone. Benefits are modest and decompression alone is still more cost-effective (Alvin, et al., 2016).

The study by Ghogawala et al. (2016) includes patients with symptomatic lumbar grade I spondylolisthesis with lumbar SS. Their patients who underwent decompression surgery plus fusion, have modest but clinically meaningful better outcomes than patients gain with decompression surgery alone. It is interesting that patients who initially underwent only decompression surgery and subsequently had reoperation with fusion, also increase in scores regarding quality of life and better disability outcomes. Consequently, without the possibility of subsequent fusion during the study, patients' outcomes with decompression surgery alone might be even worse.

In Försth's study, decompression surgery plus fusion does not show better clinical outcomes than decompression surgery alone (Försth, et al., 2016). This holds for two and five years after surgery. Patients who underwent fusion surgery have longer operating time, increased costs and longer hospitalization than patients who underwent only decompression surgery. In accordance to our lumbar SL case, Ghogawala's study focuses also on patients with lumbar SL and consecutive SS (Ghogawala, et al., 2016). Instead, Försth et al., include patients with or without lumbar SL in their study (Försth, et al., 2016). This might be an explanation of different results between the two recent published trials.

A very recent published systematic review shows similar results as Försth et al. (Dijkerman, Overdevest, Moojen, & Vleggeert-Lankamp, 2018). They also compare decompression to decompression surgery plus fusion in patients with symptomatic lumbar SS and degenerative lumbar SL. They favor decompression alone because it is the more cost-effective technique. It is associated with fewer complications than decompression plus fusion. But nevertheless they mention a few indications where decompression surgery plus fusion is more favorable. This is for example in patients with high-grade spondylolisthesis or low-grade spondylolisthesis in combination with foraminal stenosis or vertebral instability. Even though fusion surgery is more invasive, it might prevent progression of listhesis and it might reduce reoperation rates in these special cases.

Since the question about additional fusion or not is not totally clear so far, further research about surgical therapy of lumbar SL might bring new scientific evidence for treatment indications.

In contrast to our results, a recent published study obtains different results (Lubelski, et al., 2018). They compare decision-making for patients suffering from SL and LBP, and patients suffering from SL without LBP between spine surgeons in the US. Their results show that geographical location of the attending physicians influences their decision-making for patients suffering from SL with LBP. Physicians located in the Northeast recommend posterolateral fusion more than twice as often as physicians from the Southeast and Southwest. An older study by Lubelski has already shown that the geographical location of the physicians surveyed leads to significant differences in treatment recommendation (Lubelski, et al., 2016). Our study does not take into account the geographical influence on decision-making.

In addition to the geographical location, experience in the form of treated patient cases, also seems to have an influence on physicians decision-making in Lubelski's more recent study. Surgeons who treated more than 300 patients with SL and LBP have 46% agreement on their treatment recommendation, whereas surgeons with a 100 or less patient cases only reach 28-31% agreement on treatment recommendation. These results suggest that surgeons with more practice have less variability than surgeons with less experience. This is in contrast to our survey because both groups have a comparable experience regarding the lumbar SL case (*Table 5*).

Furthermore, it is interesting that in our study the number of patient cases for SL (measured as SL surgeries performed), are the lowest in comparison to our other patient cases. Nevertheless, this is the only patient case where no significant differences in decision-making between neurosurgeons and orthopedic spine surgeons exist.

Although we find no differences in decision-making between specialties, Lubelski et al. show significant differences between decision-making of neurosurgeons and orthopedic spine surgeons for patients suffering from lumbar SL. For patients suffering from SL without LBP, orthopedic spine surgeons are twice as likely to perform posterolateral fusion and only half as likely to perform laminectomy/foraminectomy without fusion (Lubelski, et al., 2018). This is consistent with the results for SL from Irwin's study (Irwin, et al., 2005).

4.5 Limitations of the study

At first sight, a possible limitation of our study could be the number of participants. Although our response rate of almost 80% is remarkably high, we could question only a percentage of all neurosurgeons and orthopedic spine surgeons in Germany. At this point, however, it should be emphasized again that we have only included participants with a lot of experience and operative activity in the area of spine surgery in our study and not the general, established neurosurgeon or orthopedic surgeon who has little or no experience with this topic. In this context the overall number of 122 participants can be considered as representative for the specific group concerning our study.

A minor shortcoming of our study is that we did not explicitly ask our participants about a completed or started spine fellowship or certificate. It would have been interesting to see whether participants with completed or started spine fellowships indicate their treatment more often according to the state of the science and whether their decisions are more often based on literature.

Furthermore, we do not include factors such as cost-effectiveness, general pressure of costs, finite resources, and limited capabilities in our survey. These factors may have an influence over physicians' decision-making and treatment recommendation. It is possible that small or private hospitals are under a different cost pressure than university hospitals. The biggest pressure of costs would probably be on physicians working in medical practices, but we did not include those in our study.

Lastly, another limitation of our study might be that we have not verified the depth of the emotional relationship between physician and patient. Also the quality of the emotional relationship has not been further investigated. Nevertheless, with our setup we can already show a trend towards a more conservative approach when treating relatives. This certainly can be further investigated in the future.

4.6 Significance and implications

Our survey is one of the first attempts to systematically investigate variations in decision-making for lumbar degenerative spinal pathologies in Europe. With our survey, we could detect some significant differences of high socioeconomic importance. The comparison of neurosurgeons and orthopedic spine surgeons within European countries is still very scarce. But with our study, we show significant differences between decision-making of neurosurgeons and orthopedic spine surgeons. A possible reason for those differences could be different residency programs. The results of our study regarding scientific evidence also underline very clearly that in spinal surgery a homogeneous and high-quality education is absolutely necessary to guarantee a good EBM. In this context, it could be useful to integrate resident neurosurgeons and orthopedic residents in spinal internships or to generally include spinal conditions more extensively in the residency programs. With the additional certification of the German Spine Society as a spine center and spine surgeon, a first step has already been taken.

Future research should focus on the extent to which these innovations can influence and improve the indication in spinal surgery.

Decision-making and personal emotional involvement is a topic with little scientific literature. Our study can be considered as a first attempt to investigate differences in decision-making due to personal involvement. Our study shows a first trend towards a more conservative approach in decision-making when emotional involvement exists. This laid the foundation for further research on this topic. Those studies should try to create an even more intense personal emotional relationship. It would be very interesting if this leads to even more differences in decision-making. But confirming or disconfirming of this aspect is an aim of future investigations.

It would be interesting if further studies investigate the situation in European countries so that the results can be compared and, further reasons for the variation in the indication of spinal surgery can be found. It is obvious that more studies and also cross-national studies concerning this subject are necessary to ensure a homogeneous quality between the medical specialties and to investigate whether our variation in treatment indications are also present in other countries.

4.7 Conclusion

The response rate of 78.7% indicates the importance of this topic for dedicated spine surgeons. Our study is one of the first in Europe, which find significant differences in decision-making between medical specialties for common lumbar degenerative pathologies. In 2 out of 3 cases, we reject the hypothesis that medical specialty affiliation does not affect the indication in spinal surgery. For cases of lumbar DH and lumbar SS, our study shows considerable differences in decision-making between neurosurgeons and orthopedic spine surgeons. Especially for the lumbar SS case, where high quality data from large multicenter trials provide treatment recommendations, it is interesting that we find such significant variations in decision-making between neurosurgeons and orthopedic spine surgeons.

In terms of decision-making and personal emotional involvement, we do not show any significant differences, however, we observe a trend towards a more conservative treatment when indicating therapy of relatives suffering from spinal stenosis. Thus we do not reject the hypothesis that emotional relationship does not impact the treatment indication in spinal surgery.

In all three patient cases we find no significant differences in the indication due to experience, measured by the years of board certification. Thus, we cannot reject the hypothesis that experience of board-certified surgeons does not influence the indication of spinal surgery.

Furthermore, our study shows that only a quarter of our participants refer to scientific literature being the basis of their decision-making. This is an alarmingly low number at the time of EBM, especially considering that there is clear level I evidence for all three pathologies and that we only include participants from spine centers or surgeons specialized in spine surgery.

Summing up, these results show the importance of a more homogenous training regarding spinal conditions for both specialties during residency. Furthermore, this study underlines the value and necessity of spine fellowships and other certifications for spine surgery that promote professional and quality education, and standardized procedures in spine surgery. This could improve not only the therapy of LBP due to degenerative pathologies, but it may also help to establish a clear treatment indication in spinal surgery.

5. SUMMARY

5.1 English

Low back pain (LBP) is one of the most common reasons to seek for medical advice with a lifetime prevalence of more than 80%. The three most common degenerative pathologies causing LBP are lumbar disc herniation (DH), lumbar spinal stenosis (SS), and lumbar spondylolisthesis (SL). Although there is current and clear level I evidence regarding treatment indication for those three pathologies, indication for spinal surgery still varies widely. Due to the high socioeconomic impact of LBP and because indications still vary despite existing level I evidence, we created the INDIANA (**Indica**tions in spi**nal** surgery) survey, an internet-based questionnaire, which investigates this important topic.

The aim of this study is to investigate whether the indications of German physicians for degenerative spinal pathologies deviate from the current state of science and to find reasons for this variation. Since surgeries on the spine are performed by neurosurgeons and orthopedic spine surgeons, the affiliation to a medical specialty may be one reason for the variation in the treatment indication. On the other hand, a personal emotional involvement to the patient can possibly influence the indication of the treating physician. Furthermore, clinical experience can also lead to such variations. These three possible reasons (medical specialty, personal emotional involvement, experience) for the variation in treatment indications, despite available scientific evidence, are investigated in our study based on patient cases.

Our questionnaire comprises a total of three patient cases, matching the three most common causes of specific back pain, for which there is clear scientific evidence. Throughout Germany, we interviewed spine specialists from neurosurgery and orthopedic spine surgeons who work conservatively and surgically in German hospitals. Our total of 122 participants were asked to name an indicated treatment for each patient case. To obtain a comparison between the two disciplines, we compare treatment indication of neurosurgeons with those of orthopedic spine surgeons. To find out whether the personal emotional relation influences the treatment indication, the participants are divided into two groups: the patient group (PG) which should advise a normal patient and the relative group (RG) in which the doctor should imagine that a relative is the patient to be treated. The results of these two groups are compared. In order to investigate the role of experience more closely, physicians with less than 10 years of board certification and physicians with 10 and more years of board certification are included in the study. Their indication is also compared to each other.

For lumbar disc herniation the state of science is that one can do surgery but does not have to. That is why we compare conservative therapy with surgical therapy. Our results show that in this case orthopedic spine surgeons recommend conservative treatment significantly more

frequently than neurosurgeons (p=0.0011, OR=4.1, 95% CI=[1.7 - 9.7]). We obtain similar results in the case of spinal stenosis, although the scientific evidence indicates a surgical procedure in the sense of decompression. 67.1% of neurosurgeons recommend decompression, whereas only 34.6% of orthopedic spine surgeons choose it (p=0.0004, OR= 3.9, 95% CI=[1.8 - 8.2]). Only in the case of spondylolisthesis there are no significant differences between medical specialties. More than 93% of the participants follow the current doctrine, namely decompression with spinal fusion.

In none of the three patient cases we could show that the treatment indication is influenced by a personal emotional involvement to the patient. However, we observe an increased trend towards conservative treatment indications for relatives.

With regard to experience, in 2 out of 3 cases, we can also observe an increased trend that the indication of physicians with less than 10 years of board certification corresponds slightly more often to the state of science.

It should be noted that only a quarter of all participants state that their indication is based on scientific evidence. This is an alarmingly low proportion in times of evidence-based medicine.

The high response rate of 78.7% shows how important this topic is among spinal surgeons. Nevertheless, our INDIANA survey is one of the first to investigate the reasons for the variation in the treatment indication for degenerative spinal pathologies. The observed differences between the disciplines could arise due to different training emphases during residency. This aspect should be investigated in further studies.

For the future, a more consistent and high-quality evidence-based training in the field of spinal surgery should be pursued. This will make it possible to achieve a uniform indication for degenerative spinal pathologies in line with the state of the art.

5.2 Deutsch

Rückenschmerzen im Lendenwirbelsäulenbereich sind mit einer Lebenszeitprävalenz von über 80% einer der häufigsten Gründe einen Arzt zu konsultieren. Die drei häufigsten degenerativen Ursachen des Rückenschmerzes sind der lumbale Bandscheibenvorfall, die Spinalkanalstenose und die Spondylolisthese. Obwohl es für diese drei Pathologien klare Therapieempfehlungen mit hoher wissenschaftlicher Evidenz gibt, variieren die Indikationsstellungen enorm. Aufgrund des hohen sozioökonomischen Einflusses von Rückenschmerzen und weil die Therapieindikation trotz vorhandener wissenschaftlicher Evidenz nach wie vor variiert, erstellten wir die INDIANA (**Indi**ca**t**ions in spi**na**l surgery) Studie, einen Onlinefragebogen, der sich mit diesem wichtigen Thema auseinandersetzt.

Das Ziel dieser Studie ist zu untersuchen, ob die Indikationsstellung deutscher Ärzte bei degenerativen Wirbelsäulenerkrankungen vom aktuellen Stand der Wissenschaft abweicht und Gründe für diese Abweichung zu eruieren. Da Eingriffe an der Wirbelsäule von Neurochirurgen und Orthopäden vorgenommen werden, kann zum einen die Facharztzugehörigkeit ein Grund für die Abweichung der Indikationsstellung sein. Zum anderen kann eine persönliche emotionale Bindung zum Patienten möglicherweise die Indikationsstellung des behandelnden Arztes beeinflussen. Des Weiteren kann auch die jeweilige klinische Erfahrung zu unterschiedlichen Indikationsstellungen führen. Diese drei möglichen Gründe (Facharztzugehörigkeit, persönliche emotionale Bindung, Erfahrung) für die Abweichung der Indikationsstellung trotz vorhandener wissenschaftlicher Evidenz werden in unserer Studie anhand von Patientenfällen untersucht.

Unser Fragebogen umfasst insgesamt drei Patientenfälle, passend zu den drei häufigsten Ursachen des spezifischen Rückenschmerzes, für welche eine klare wissenschaftliche Evidenz besteht. Deutschlandweit befragten wir Wirbelsäulenspezialisten aus der Neurochirurgie und Orthopädie, welche aktiv konservativ und operativ in spezialisierten Wirbelsäulenzentren und Krankenhäusern tätig sind. Unsere insgesamt 122 Teilnehmer sollten zu jedem Patientenfall eine indizierte Therapie nennen. Um einen Vergleich zwischen den beiden Fachdisziplinen zu erhalten, stellen wir die Therapieempfehlung von Neurochirurgen denen der Orthopäden gegenüber. Um herauszufinden ob der persönliche emotionale Bezug die Therapieindikation beeinflusst, wurden die Teilnehmer auf zwei Gruppen aufgeteilt: die Patientengruppe (PG) welche einen normalen Patienten beraten sollte und die Verwandtengruppe (RG) in welcher sich der Arzt vorstellen sollte, dass ein Verwandter der zu behandelnde Patient sei. Die Ergebnisse aus diesen beiden Gruppen werden miteinander verglichen. Um die Rolle der Erfahrung genauer untersuchen zu können, wurden Ärzte mit weniger als 10 Jahren Facharzterfahrung und welche mit 10 und mehr Jahren Facharzterfahrung in die Studie eingeschlossen und ihre Therapieindikation jeweils miteinander verglichen.

Für den lumbalen Bandscheibenvorfall ist der Stand der Wissenschaft, dass man operieren kann, aber nicht muss. Deshalb vergleichen wir die konservative Therapie mit der operativen Therapie. Unsere Resultate zeigen, dass in diesem Fall Orthopäden signifikant häufiger eine konservative Therapie empfehlen als Neurochirurgen (p=0.0011, OR=4.1, 95% CI=[1.7 – 9.7]). Ähnliche Resultate erhalten wir für den Fall mit der Spinalkanalstenose, obwohl die wissenschaftliche Literatur hierfür eine operative Vorgehensweise im Sinne einer Dekompression empfiehlt. 67,1% der Neurochirurgen empfehlen eine Dekompression, wohingegen nur 34,6% der Orthopäden diese wählen (p=0.0004, OR= 3.9, 95% CI=[1.8 – 8.2]). Nur im Spondylolisthese-Fall gibt es keine signifikanten Unterschiede zwischen den Fachdisziplinen. Über 93% der Teilnehmer folgen der aktuellen Lehrmeinung, nämlich der Dekompression mit spinaler Fusion.

In keinem der drei Patientenfälle kann gezeigt werden, dass die Therapieindikation durch eine persönliche emotionale Bindung zum Patienten beeinflusst wird. Allerdings beobachten wir einen vermehrten Trend von konservativem Vorgehen bei der Therapieindikation für Verwandte.

Hinsichtlich der Erfahrung können wir in zwei von drei Fällen ebenfalls den vermehrten Trend beobachten, dass die Indikationsstellung von Ärzten mit weniger als 10 Jahren Facharzterfahrung etwas öfter dem Stand der Wissenschaft entspricht.

Erstaunlicherweise hat insgesamt nur knapp ein Viertel aller Teilnehmer angegeben, dass ihre Indikationsstellung auf wissenschaftlicher Evidenz basiert. Das ist ein alarmierend geringer Anteil zu Zeiten der evidenzbasierten Medizin.

Die hohe Antwortrate von 78.7% zeigt wie wichtig dieses Thema unter Wirbelsäulenchirurgen ist. Trotzdem ist unsere INDIANA Studie eine der ersten, welche die Gründe für die Varianz in der Indikationsstellung bei degenerativen Wirbelsäulenerkrankungen untersucht hat. Es ist möglich, dass die beobachteten Unterschiede zwischen den Fachdisziplinen aufgrund verschiedener Trainingsschwerpunkte während der Facharztausbildung entstehen. Diesen Aspekt sollten weitere Studien untersuchen.

Für die Zukunft ist eine einheitlichere und qualitativ hochwertige evidenzbasierte Ausbildung im Bereich der Wirbelsäulenchirurgie weiter anzustreben. Dadurch kann man eine einheitliche und dem Stand der Wissenschaft entsprechende Indikationsstellung bei degenerativen Wirbelsäulenerkrankungen erreichen.

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7. ABBREVIATIONS

3D .... three-dimensional
AMA .... American Medical Association
BMI .... body mass index
CI .... confidence interval
COX-2 .... cyclooxygenase-2
CT .... computed tomography
DALY .... disability-adjusted life year
DH .... disc herniation
DRG .... diagnosis-related group
GDP .... gross domestic product
GPC .... German procedure classification
ILF .... interlaminar fenestration
INDIANA .... indications in spinal surgery
MRI .... magnetic resonance imaging
NSAID .... nonsteroidal anti-inflammatory drugs
LBP .... low back pain
OR .... odds ratio
PG .... patient group
RG .... relative group
SD .... standard deviation
SL .... spondylolisthesis
SS .... spinal stenosis
VAS .... visual analogue scale

8. TABLE OF FIGURES

9. TABLE DIRECTORY

10. ACKNOWLEDGEMENTS

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11. CURRICULUM VITAE

12. PUBLICATIONS

Original work

N. Sollmann, C. Morandell, L. Albers, M. Behr, A. Preuss, A. Dinkel, B. Meyer, S.M. Krieg

Association of decision-making in spinal surgery with specialty and emotional involvement- the Indications in Spinal Surgery (INDIANA) survey

Acta Neurochir (Wien) 2018, March;160(3): pp.425-438 doi: 10.1007/s00701-017-3459-7.

Abstracts

N. Sollmann, C. Morandell, M. Behr, A. Preuss, B. Meyer, S. M. Krieg

Indikationsstellung in der Wirbelsäulenchirurgie- die INDIANA Studie

Deutscher Wirbelsäulenkongress
11. Jahrestagung der Deutschen Wirbelsäulengesellschaft (DWG)
1.-3. Dezember 2016, Hannover

N. Sollmann, C. Morandell, M. Behr, A. Preuss, B. Meyer, S. M. Krieg

Indications in spinal surgery- the INDIANA trial

67th Annual Meeting of the German Society of Neurosurgery (DGNC)
Joint Meeting with the Korean Neurosurgical Society (KNS)
12-15 June 2016, Frankfurt am Main

13. APPENDIX

13.1 Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich bei der promotionsführenden Einrichtung

Neurochirurgische Klinik und Poliklinik

der TUM zur Promotionsprüfung vorgelegte Arbeit mit dem Titel

The impact of specialty, emotional involvement, and experience on the treatment indication of common lumbar spinal pathologies with clear level of evidence –
The Indications in Spinal Surgery (INDIANA) survey

in der neurochirurgischen Klinik unter der Anleitung und Betreuung durch Prof. Dr. med. Sandro M. Krieg, ohne sonstige Hilfe erstellt und bei der Abfassung nur die gemäß § 6 Ab. 6 und 7 Satz 2 angebotenen Hilfsmittel benutzt habe.

Ich habe keine Organisation eingeschaltet, die gegen Entgelt Betreuerinnen und Betreuer für die Anfertigung von Dissertationen sucht, oder die mir obliegenden Pflichten hinsichtlich der Prüfungsleistungen für mich ganz oder teilweise erledigt.

Ich habe die Dissertation in dieser oder ähnlicher Form in keinem anderen Prüfungsverfahren als Prüfungsleistung vorgelegt.

Ich habe den angestrebten Doktorgrad noch nicht erworben und bin nicht in einem früheren Promotionsverfahren für den angestrebten Doktorgrad endgültig gescheitert.

Die öffentlich zugängliche Promotionsordnung der TUM ist mir bekannt, insbesondere habe ich die Bedeutung von § 28 (Nichtigkeit der Promotion) und § 29 (Entzug des Doktorgrades) zur Kenntnis genommen. Ich bin mir der Konsequenzen einer falschen Eidesstattlichen Erklärung bewusst.

Mit der Aufnahme meiner personenbezogenen Daten in die Alumni-Datei bei der TUM bin ich einverstanden.

München, 13.11.2019 Carmen Morandell